The Construction of CUORE
Volumes II & III

Saturday, February 2, 2008

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zeropuntoquindici

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CUORE construction can be divided into four sequential, almost independent, processes: parts production/cleaning (crystals, copper pieces, detector teflon pieces, thermistors and heaters, cables/connectors, assembly/shipment/storage parts), clean pieces shipping & storage, towers construction, Towers assembly inside the cryostat. All process are supervised and controlled by (and with) the production database.

In this document a detailed description of actions, tools and process regarding parts shipment & storage and the tower assembly is given.

The production database is also discussed entering, when needed, into the details of crystals, copper and teflon production & cleaning to describe the methods to acquire and the info acquired in any specific situation.

1. The rules of the game

The approach adopted designing this part of the construction of CUORE is that it must be, as a whole, a process:

- Recontamination-free
- Easy (i.e. as much as possible error-free)
- Fast

Recontamination of clean pieces start to be effective as soon as the pieces have been cleaned. To avoid or limit as much as possible such occurrence the whole chain have been designed to be a "zero-contact" procedure where zero contact means: to avoid any contact of any pieces with the air (or not-controlled atmosphere) along the whole process, minimize their handling, minimize their lifetime out of LNGS, and have the pieces facing or touching low activity materials only.

Radon diffusion have been taken into account too designing the tools used to store and assembly the pieces..

The easiness of the process and the strict observance of the operation protocols is another way to reduce significantly the risk of recontamination. While the whole process, from pieces cleaning to installation in the cryostat, could last order of years a severe recontamination, due to operator errors or misunderstanding of the procedures, could occur in very short time.

Provided that the first two rules have been respected, the time is the last but not the least issue. The less it takes to complete the process the less will be the integrated dose accumulated by ours pieces by, for example, radon diffusion .

But in no way time arguments should be used to reduce the effectiveness of rules 1 and 2.

As for now many steps of the production and cleaning of the individual pieces have not yet well defined, as well as some aspect of the final design of the assembly.

Here we assume as baseline the following:

- All the pieces will arrive at LNGS as ready-to-mount
- Crystal will be produced in China
- All copper parts (frames, pillars, screws, cable rail, tower top plate, shields etc...) will be cleaned in Legnaro
- Teflon holders will be cleaned at LNGS
- No last-minute cleaning will be part of the standard assembly chain
- The baseline for the tower design is the current CAW configuration (that with Teflon holders)
- Tower cabling will be made by means of cable strips
- Bonding will be done on the assembled tower put in vertical position

If any of these statements will not be true then, part of, or all of this document should be revised.

2. Be aware of Recontamination.

The production of crystals and copper parts for CUORE will last 32-34 months. If we take in to account the effects induced by cosmic rays on raw materials starting from their bulk purchase the period we have to take care to minimize the contamination is even longer.

This means that we have to store as much as possible raw materials underground, we have to monitor and minimize the time they are out for machining, we have to protect and ship them back to LNGS as soon as they exit their last cleaning process, we have to foreseen a long term storage strategy to minimize Radon diffusion effects as well as design clean, air tight assembly tools and deploy assembly procedures with minimal handling and clean contacts.

The same should be true even for the consumables (powders, acid, soap etc..) or tools (gloves, boxes, holders etc…) we use to process, handle, mount those pieces.

All these actions are going to be the result of a compromise among different needs, sometimes in conflicts among them. Packaging, for example, must take into account several issues: protection of the pieces from mechanical shock during shipment, assembly needs in terms of number and kind of pieces inside any pack, handling and environmental conditions at production sites, long term storage issues etc…

To have all these stuff under control over a long period of time it is really important to start from the very beginning (i.e. from yesterday) to keep track of the story of each piece from it's born as raw material up in a standard and organized way. The tool to do that is called the production database.

To be aware of recontamination and to be sure that all the actions described in this document will be effective and coherent some quantitative information are needed and should be reported in this chapter.

In the following I summarize (only) the main methods and materials we have chosen to minimize the risk-of and the recontamination that should be supported by some quantitative argument both on the level of contamination expected due to the direct contact, and the level of contamination expected due to radon diffusion through materials.

Polyethylene wrapping: whenever it is possible pieces are triple wrapped in 100μm thick polyethylene bags under vacuum (the vacuum is done independently in all the bags). In most of the cases the whole surface of the piece is and will be in direct contact with this material for years. Info needed: An estimate of the target vacuum level. An estimate of the activity of THIS polyethylene , the expected effect on the background after one year of storage.

Reber Box: Air tight Food storage box with vacuum valve. Whenever it is possible wrapped pieces are put inside an air tight polycarbonate box, under vacuum. This box will be used also to store naked (not wrapped) crystals after gluing. Info needed: An estimate of the target vacuum level must be done.

Commercial Box: whenever Reber boxes cannot be used (too large, too small etc..) commercial boxes are used. Vacuum is done by wrapping all the box with a polyethylene bag.

Typically are used when also the direct wrapping of the piece is not recommended. Pieces are hold inside the box by PTFE supports.

Custom made Box: whenever neither Reber boxes nor commercial boxes are available (too large, too small etc..) custom made boxes will be used. Typically they must be done with transparent material. Recommendations on the material to be used are needed taking into account that in some case they will not take advantage of the extra protection given by the P.S.A.

Nitrogen: Nitrogen is used to flow storage closets (pieces in the boxes) to limit Radon diffusion and as last resort if wrapping or vacuum box for any reason have a failure. Nitrogen is used also to flow the glove boxes where naked pieces are assembled. Info needed: maximum allowed activity. ($1\mu Bq/m^3$ is the activity of the purified Nitrogen used by Borexino, the activity of commercial regular purity N_2 is some order of magnitude higher).

Anti-shock stuff: During shipment wrapped pieces are immersed in anti shock material. This can be polystyrene or other stuff alike. For crystals this close vicinity can last one month (the length of the trip by boat).

2.1. Radon diffusion

Radon diffusion coefficient through polymers is small but not negligible for the level of contamination required by CUORE once combined with the storage time foreseen for the first pieces produced.

This chapter is my first look at the problem just to have a raw idea of what we are talking about. More precise and detailed consideration should come from RAD.

The permeability coefficients for material that could be used for storage or assembly (Polyethylene, Polycarbonate and Plexiglas) and other materials I found in literature[4] are summarized in table 1.

The values quoted there are measured in thin film but since it doesn't appear from the table itself that higher thickness makes the permeability worse (or better) I feel free to assume these values reasonable for thicker slabs too.

At the last GM Kadel quoted in 20 Bq/m^3 the radon concentration in the underground lab at LNGS. I will check this number, but for the moment let's say that it is right and it represents the activity due to the average concentration of ^{222}Ra in equilibrium with its daughters in the place where we are going to store or assembly the towers.

Let's do the exercise taking as reference a cubic box of 1m^3. The wall of thickness dL have a permeability coefficient of the order of K=1x10^{-7} cm^2 sec^{-1}. All the six faces of the box are in direct contact with the atmosphere of a larger room where radon is present with a concentration of 20 Bq/m^3. The box, at t=0, is filled with radon-free N at the same pressure and temperature of the air of the room.

The way the radon start to diffuse inside the box is a non linear process as shown in picture 1 taken from ref [5]

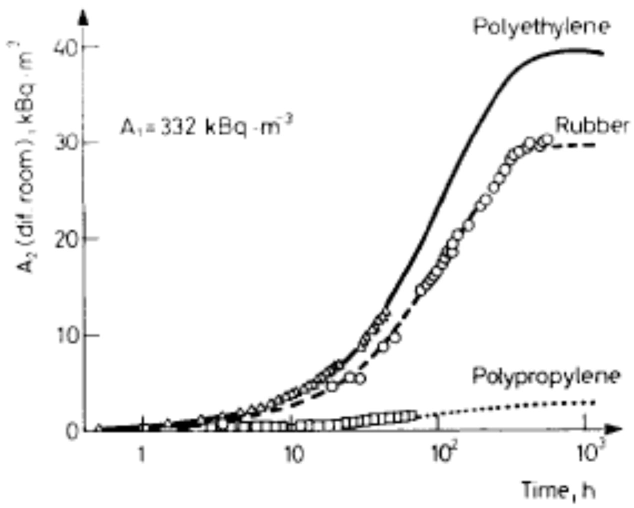

Fig. 3. Radon activities in diffusion room for different barriers. Radon activity in the radon chamber was 332 kBq·m^{-3} during exposure. Points represent experimental results and lines show theoretical calculation by Eq. (3)

Figure 1: Time dependency of radon diffusion in some materials

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[4] Permeability of radon-222 through some materials, Wafaa Arafa Radiation Measurements 35 (2002) 207 – 211

[5] Experimental study of radon and thoron diffusion through barriers. M. Durcik and F. Havlik. Journal of Radioanalytical and Nuclear Chemistry. 209 (1996) 307-313

By assuming a linear growth (hence overestimating the effect) we get an increase of the activity inside the reference box of 1.2 x 10^{-13} Bq/cm^3*sec. The Radon concentration in the box will equal that of the room after 1.6 x10^8 sec, i.e. after, more or less 1929 days.

The maximum exposure time calculated by Kadel to keep the background of a tower below 0.01 events/kg/KeV/year is 15 minutes at 20 Bq/m^3 (A very pessimistic picture since the sticking factor have been set to one, but to have an upper limit it can be a good starting point). Our storage time will be much longer. To get the same integrated dose in one year or more we must keep the radon concentration much lower.

Thus, for example, if we want in our box and in one year the same integral activity shown by $1m^3$ of air at 20 Bq/m^3 in 15 minutes the average concentration of Radon in the box should be maintained below 5.7 x10^{-10} Bq/cm^3.

With the diffusion rate calculated before, this level of activity is reached in 80 minutes.

Note that this concentration is orders of magnitudes greater then the $1\mu Bq/m^3$ activity of the purified Nitrogen used by Borexino but very close to the activity of commercial regular purity N_2[6]. By the way the level of purity of this gas define the minimum activity we can imagine to have in any storage or assembly system where the strategy used to fight Radon induced recontamination is flowing some gas inside an air tight box.

From the numbers quoted before it looks that radon diffusion is the main effect to take care of if we can use purified Nitrogen.

Diffusion level can be kept under control by fluxing the box at a convenient rate ($1m^3$ per hour in our example could be enough)

For very long storage time (more then two year) probably other strategy should be investigated to keep the integral activity below the desired value at a reasonable cost. (vacuum packet box for example).

Production of purified Nitrogen have been done by Borexino at a rate of $200m^3/h$ with two liquid-solid-chromatography column with 11.5 l activated carbon[7].

In this exercise I used as example a box with a quite high K. In the real life the usage of materials with high K (Plexiglas for example) can be limited to the glove box where "transparency" is a must. The garage or the storage boxes (the kind of tools where pieces will rest for most of the time) could be done with polycarbonate or steel which have a much lower K.

Conclusion: it looks that even in the worst case (sticking factor equal 1 + overestimated diffusion rates + not optimized choice of materials) we can keep the radon concentration low enough just fluxing at a convenient rate commercial grade Nitrogen.

There are also many ways to minimize further the radon concentration by using evaporated or purified Nitrogen and by choosing, whenever it is possible, materials with lower diffusion coefficient both for storage closets & boxes and for the assembly glove boxes.

2.2. recontamination by direct contact

(here goes any argument that can drive the choice of materials, like gloves, tools, etc... that will be in direct contact with copper and crystals)

2.3. recontamination by activity of close object

(here goes any argument that can drive the choice of materials close but not in contact with copper and crystals which activity could be risky

[6] Radon Measurements for the Solar Neutrino Experiment Borexino. B. Freudiger. Progress in Particle and Nuclear Physics 48 (2002) 23-24

[7] G. Heuser et al. Appl. Rad. & Isot. 52 (200) 691-695

Table 1: radon permeability of some material (ref. 1)

Material	Sample thickness (cm)	$R = N_2/N_1$	Permeability constant ($cm^2\ s^{-1}$)	Permeability (%)	Sample thickness (cm)	Permeability constant ($cm^2\ s^{-1}$)
Aluminized polymers						
Aluminized polycarbonate	0.002	0.331	3.61×10^{-9}	1.23		
Aluminized mylar	0.0005	0.119	2.46×10^{-10}	0.08		
Polymers						
Polycarbonate	0.025	0.188	2.10×10^{-8}	7.17	0.00148	0.55×10^{-8} (A)
					0.00253	3.8×10^{-9} (R)
					0.00254	3.82×10^{-9} (G)
Polyethylene terephthalate	0.022	0.270	2.96×10^{-8}	10.1	0.00120	0.3×10^{-8} (A)
					0.00176	8.37×10^{-10} (R)
					0.00178	8.36×10^{-10} (G)
Hydrated cellulose	0.012	0.455	3.64×10^{-8}	12.4		
Cellulose nitrate (CN 85)	0.0115	0.280	1.63×10^{-8}	5.6	0.00147	1.25×10^{-7} (R)
					0.000153	1.24×10^{-7} (G)
PVC cling	0.012	0.096	0.463×10^{-8}	1.58	0.00098	0.58×10^{-8} (A)
					0.00550	5.02×10^{-8} (R)
					0.05330	5.0×10^{-8} (G)
					x	42.0×10^{-8} (W)
Polyallyldiglycol-carbonate (CR-39)	0.11	0.290	1.64×10^{-7}	56		
Polyester	0.2	0.132	4.34×10^{-8}	14.8	0.00152	1.97×10^{-9} (R)
					0.00152	1.95×10^{-9} (G)
Makrofol	12×10^{-4}	0.103	5.0×10^{-10}	0.17		
	10×10^{-4}	0.125	5.81×10^{-10}	0.19		
	8×10^{-4}	0.138	4.17×10^{-10}	0.14		
	6×10^{-4}	0.133	3.34×10^{-10}	0.11		
	5×10^{-4}	0.132	2.77×10^{-10}	0.10		
	2×10^{-4}	0.379	4.45×10^{-10}	0.15		
Polyethylene	0.001	0.384	2.27×10^{-9}	0.78	0.00702	7.80×10^{-8} (A)
					0.00251	3.35×10^{-9} (R)
	0.012	0.281	1.71×10^{-8}	5.84		
	0.019	0.270	2.57×10^{-8}	8.77		
	0.025	0.230	2.72×10^{-8}	9.28		
	0.033	0.115	1.57×10^{-8}	5.40		
	0.0375	0.209	3.60×10^{-8}	12.3		
	0.04	0.140	2.38×10^{-8}	8.12		
Plexiglas (Polymethylmethacrylate PMMA)	0.3	0.130	1.62×10^{-7}	55.30	x	5.0×10^{-7} (W)
	0.5	0.123	2.55×10^{-7}	87.03		
	0.6	0.095	2.30×10^{-7}	78.50		
Papers						
Waxed paper	0.002	0.433	5.56×10^{-9}	1.89		
Filter paper	0.015	0.964	1.46×10^{-6}	498		
A4-Xerox paper	0.01	0.890	2.93×10^{-7}	100		
Glass						
Glass	0.3	0.135	1.72×10^{-7}	59		

G: Giridhar et al. (1982), A: Abdel-Fattah et al. (1986),R: Ramachandran et al. (1987), W: Wojcik (1991) and x: The value of material thickness is not mentioned.

3. The production database

3.1. *Motivations*

To maintain over a quite long period of time the vital attention needed to fulfill, for any single pieces of the detector, the goal of a "recontamination-free" procedure, all the actions must be programmed in advance. No space for improvisation or unforeseen events can be allowed.

Protocols and detailed manuals can be written (and will be written) but to keep a coherent and uniform attitude on all the details of a production going to last years could not be enough.

In this sense a production database and the actions needed to record production progress, measures results, action taken etc… can be of great help by providing a tool to put unavoidable and fixed "check points" along the construction path able to enforce the respect of protocols and procedures.

Another field where our database can play a role is to trace and monitor the production and its progress and help in pieces handlings. Detectors components are produced and cleaned in different sites any with its own time schedule, procedures, and Quality Controls: TeO2 Crystals are done at SICCAS in china, Copper parts in Legnaro, Teflon pieces produced in Italy and cleaned at LNGS. Along with the detector parts many other components must be procured, made, cleaned, stored to be available in the right place at the right time.

As stated in the previous chapter the database is very important too to have a complete picture of the exposure of our pieces to hostile environments and object.

Less important for CUORE is, instead, to focus the scope of the production database on the opportunity to trace back and solve problems that could occur once the detector is running. Our experiment is, on all the relevant aspects (resolution, background), like a satellite. Once is out , if it doesn't works we have lost and the game is over.

This last statement is not true for CUORE0. In this case, if problems arise, a complete picture of what have been done can really help to spot the weak point and find an alternative solution.

Motivations for the database can hence be summarized as follow:

- have procedures and actions clearly established that help us in keeping a coherent and uniform attitude over the years the production will last
- keep tracks of any relevant production/QC steps
- help managing all those pieces
- have a way to trace back problems if they will occur in CUORE/0

3.2. *Overview and guideline*

The design outlined in this chapter is a proposal that match the requirements before mentioned AND it's modular enough to have all (and only) the relevant parts done just in time for the start up of the crystals production chain foreseen for the end of February.

It is VERY important that for ANY production chain the first day of work would be identical to the last one. So whatever alternative technology or approach people would like to propose it MUST satisfy this temporal constraint.

A stated before the production and handling of CUORE components is spread over many sites. Moreover not all the production chains are already completely designed and they will not start all at the same time. The first to start will be crystal production.

Hence the production database system must be:

- scalable: must be possible to add production sites and their output following their readiness.
- distributed: any site must have it's own Data Acquisition Points facility to acquire, format and send data to the database
- safe: nobody , at production sites, have direct write-access to the database
- easy: any Data Acquisition Point is designed to do a specific task in a specific place. The GUI of the DAQ software (the interface between the operator and the database) must be tuned to be understood by the actual operators on site
- readable by everybody

The design of the system proposed here is based on a central server running a product like PostgreSQL at LNGS. This computer already exist and it is the CPU serving the CUORE CUORICINO db.

DAQ Stations are any computer on site with network access where the DAQ software can be installed. The actual computer location must be coherent with the kind of data the operator must collect and send. Some procedures require to be recorded as soon as they have been done; in this case the DAQ station must be available where the job is done. In other situation is enough that at the end of a process data are collected and sent to the db; in this case the DAQ station can be a computer far from the work area, for example, in any office.

DAQ software provide an interface to the operator to standardize and simplify data input. Every time data are input by hand (not collected by means of barcode reader or other equipment like this) the software must have a consistency check to avoid the transmission of wrong data (typically mistype) or badly formatted data.

DAQ software must be a robust, no frill tool. The GUI must account for the actual operators skills and the possibility that operators at remote site can change over time without notice and minimal training on the subject.

DAQ software is localized. Supported languages are: Chinese in China, Padano at Legnaro, Abbruzzese at LNGS. The db query interface is in English

DAQ procedure ends sending (via FTP or alike) the data to the DATA interface program running on the server at LNGS.

Data interface software, read the data file and distribute the info into the tables of the database.

The db is organized in tables and relations organized by production chain.

Only the Production Master can write directly into the database.

By means of the database (see for example the Chinese case study) some interlock to the production chain can be set or released. Process interlocks can be enforced by contract (as the Chinese case) or by software (for example making it impossible to set as entered in the assembly chain a crystals flagged as "contaminated")

As soon as new production chain is understood and ready to start new DAQ stations are added to the system, the Data Interface updated and the new sets of tables and relations added to the db.

The db is served over internet and accessible read-only by everyone.

3.3. The First Priority

Since crystal production is almost ready to start the first priority is provide SICCAS, from the very beginning, with all the instruments needed to acquire and send to LNGS all the information foreseen in the production protocol.

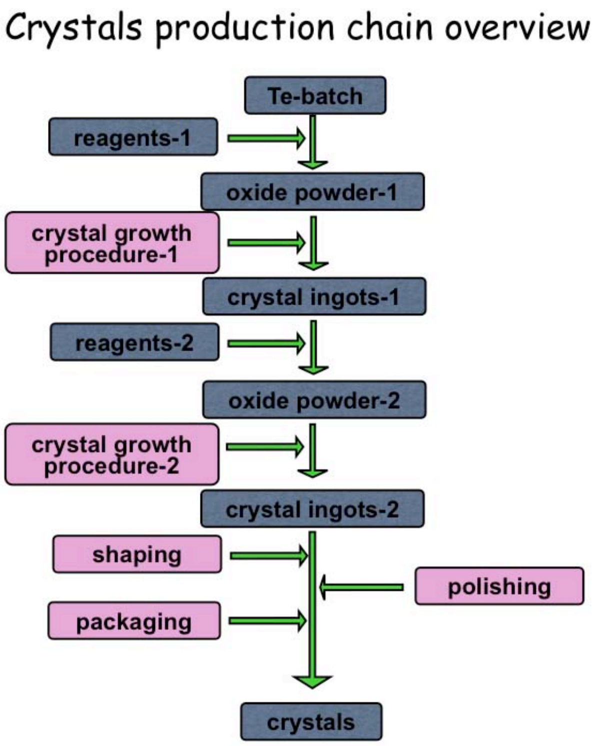

Figure 2: Crystal production chain overview

In the framework of the design proposed this means that at least the DAQ software (interface) must be written and tested in situ. On the server side, at the very beginning it is enough an FTP server configured and running.

In this way the work at SICCAS can start in strict accordance with all the procedures foreseen by the production protocol. The development of the Data Interface Script and of the db itself can follow in short time few weeks later.

For the reasons stated in chapter 2 would be very important to start to fill the database with the story of the raw materials already purchased currently stored at LNGS but about to leave the underground site to be machined.

3.4. *The crystal production db @ SICCAS*

The main steps of crystal production are illustrated in picture 2.

The production protocol foreseen, other then the collection of several information regarding materials and procedures, a semaphore system (acknowledge) that put in waiting state some actions until the results of some tests (rad measures on chemicals and powders) become available and are approved by the crystal production master.

This situation is schematically represented in figure 3.

In this example two DAQ stations are installed at SICCAS and one at SINAP. Using the DAQ software SICCAS send to the FTP server formatted text files with all the info on the production and materials as required by the production protocol. Before start using some chemicals or powders a sample of this material is sent to SINAP (at the beginning to LNGS too) to be tested. SINAP (and LNGS) publish on the database the table with the result of the measure. The production master (a guy somewhere in Italy) read those tables and set a positive or negative flag on the database authorizing or not SICCAS to proceed with those materials.

Other then the production master a "local production master" (our expert CUORE member in china) is asked to set interlock flag into the database too to certify that some procedures have been done in complete agreement with the production protocol.

In the next figures the complete process is shown, from the certification of the Te powder up to the crystals ready to be sent at LNGS.

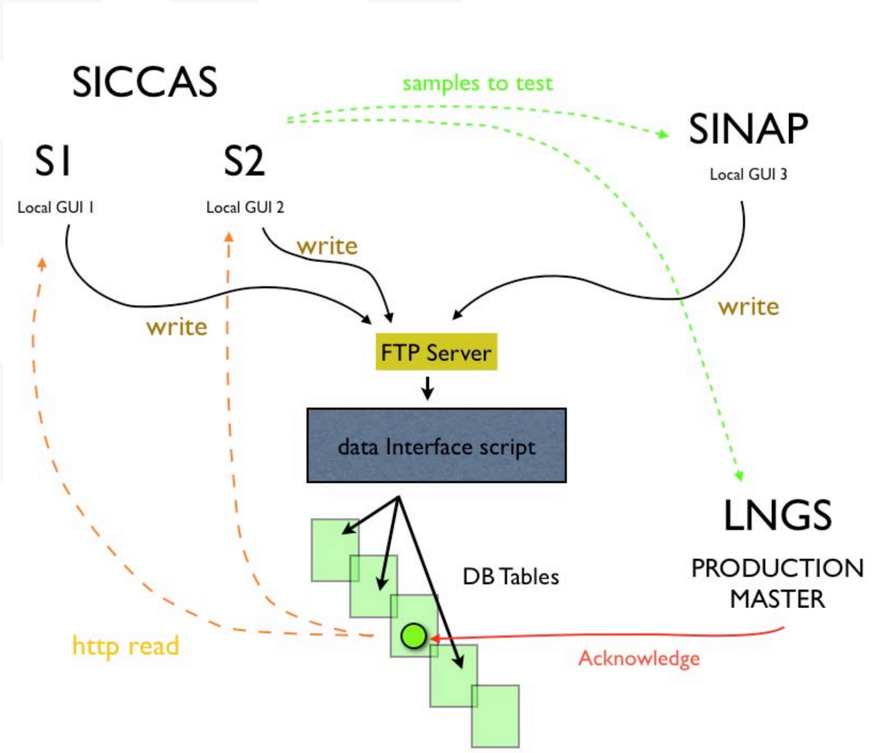

Figure 2: db at SICCAS

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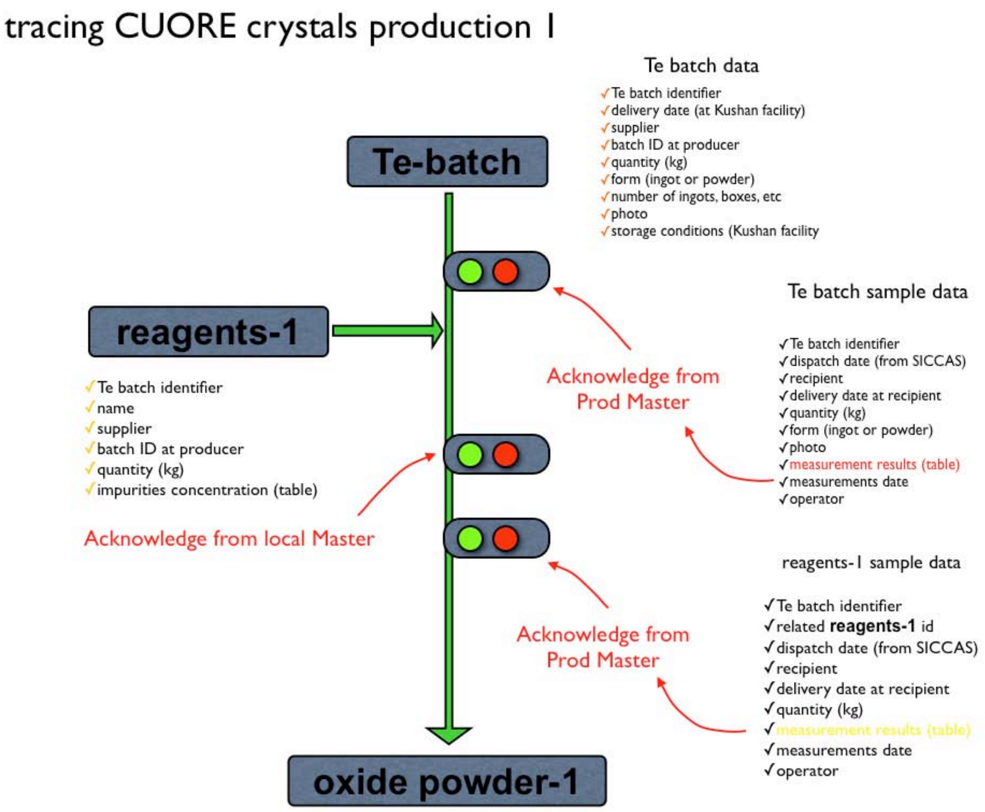


Figure 3

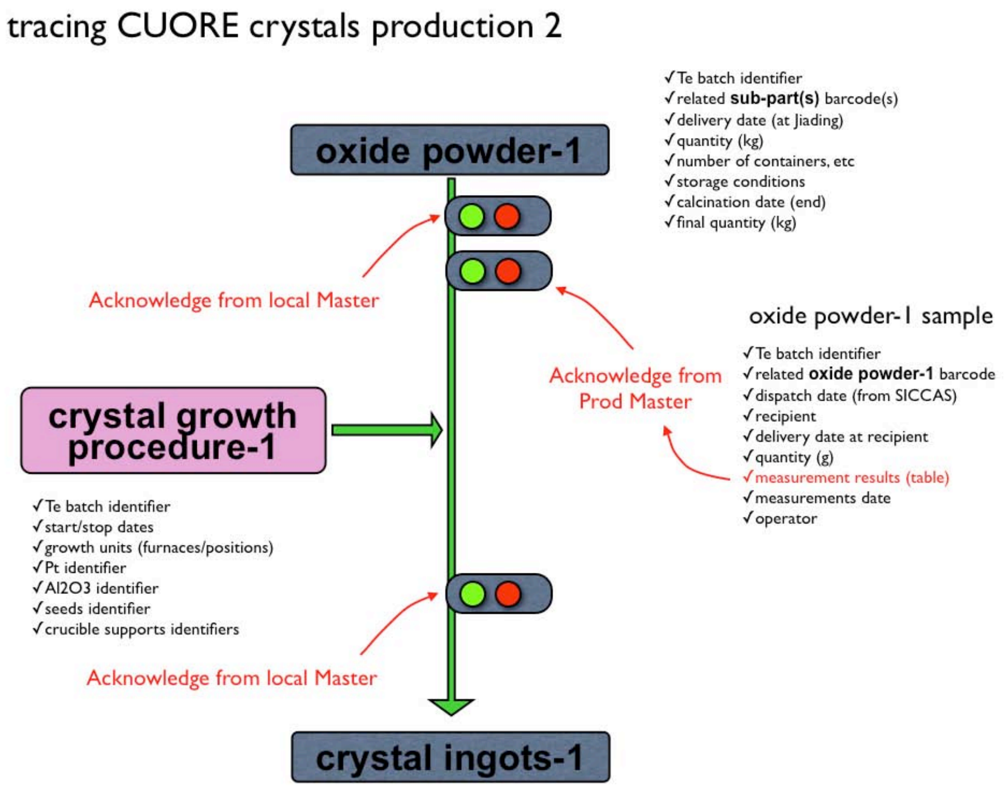


Figure 4

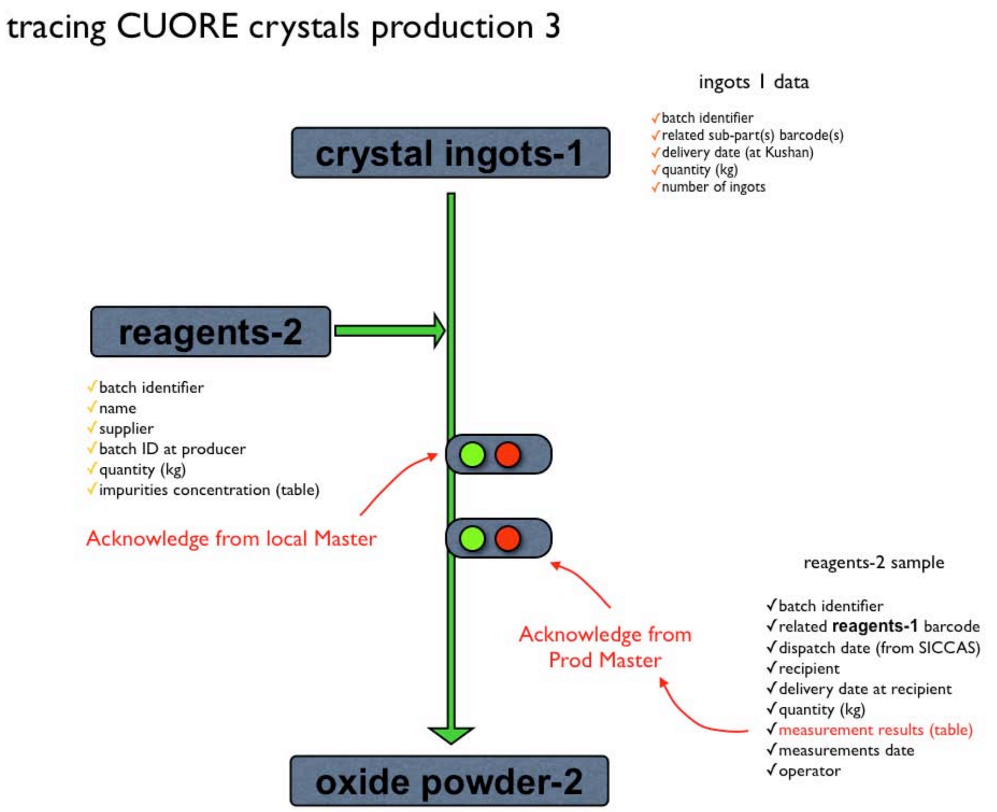


Figure 5

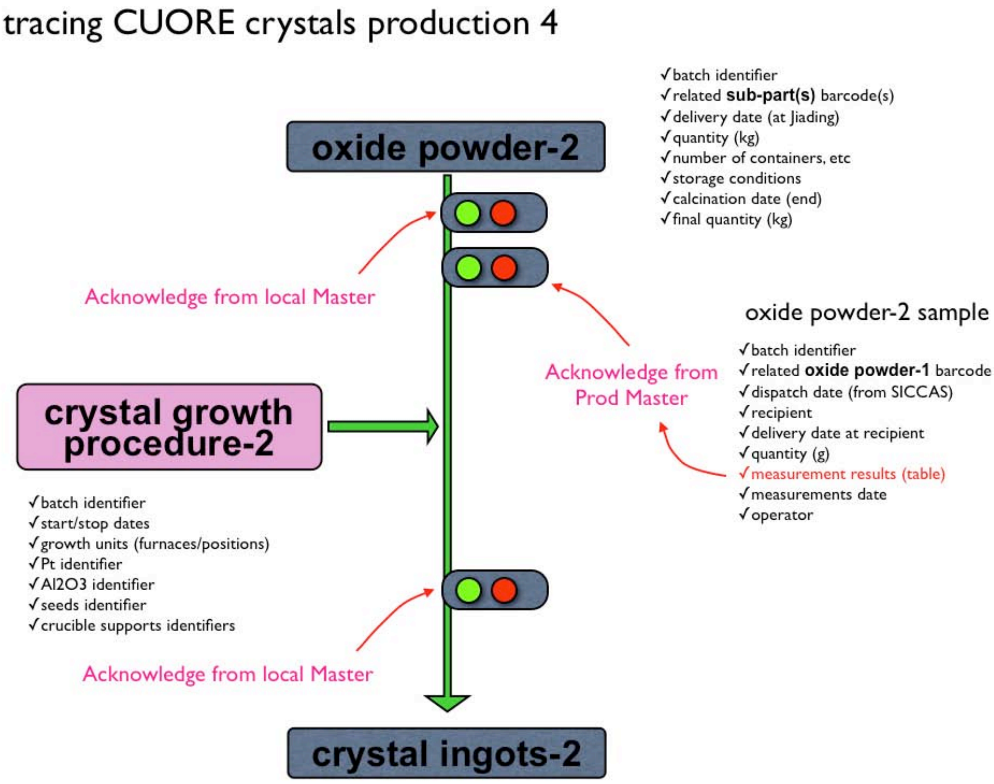


Figure 6

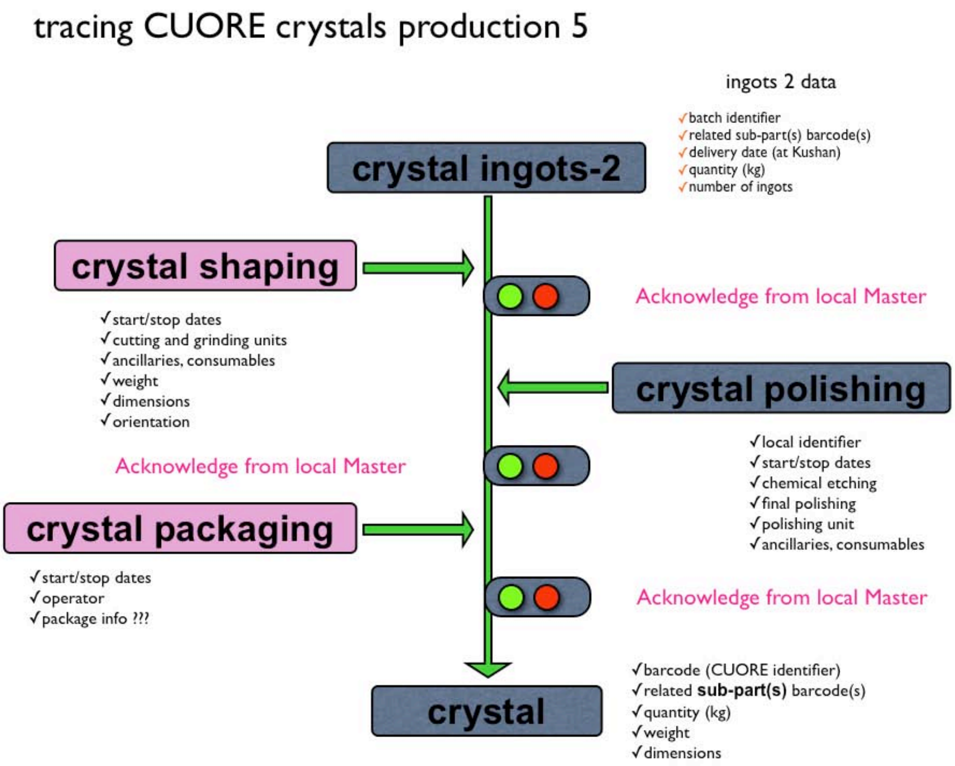


Figure 7

3.5. The copper production/cleaning db

Site: Legnaro

Preliminary suggestions: All copper parts are identified by their “LAST cleaning step” ID. Parts belonging to the same run share the same ID (for example the same number applies to all the frames belonging to the same magnetron run).

If need the ID can keep track of all the cleaning steps (for example Frame ID 302456 could means that it went through Chemical bath 30, Tumbler run 24 and Magnetron run 56)
Since this complicate quite a lot the life at LNL quite good reason to do that should support this request

The production database should contain information about the total exposure time of copper out of LNGS

3.6. The teflon holders production/cleaning db

Site: LNGS

Preliminary suggestions: Shipping info, upon arrival QC, parts in stock, reprocessing status, storage tools status, storage history QC (results of periodic checks on package integrity and action taken)

3.7. The teflon shipping & assembly parts production/cleaning db

Site: LNGS

3.8. The cable production/cleaning db

Site: LNGS
Preliminary suggestions: XXX…,

3.9. Heater and thermistor production/cleaning

Site: somewhere in the U.S.A.

Preliminary suggestions: XXX…

4. Last cleaning, shipment & storage of components and accessories

As soon as any component exit the production and cleaning stage it should be stored in a safe way and shipped to LNGS. The "zero-contact" approach of our assembly chain starts from here.

Hence the main purpose of the object used to store and handle the piece must be to avoid (minimize) recontamination induced by Radon or by contact with any non radio-pure material and to protect the pieces from mechanical shock during shipment.

We have 5 "production lines" feeding the assembly chain: crystals, copper pieces, detector teflon pieces, thermistors and heaters, cables/connectors, The last action of any line is the final cleaning of the pieces to be delivered.

For the purpose of this document it's not important to define exactly how these production lines work but to understand how the productions are organized, their delivery capability and the impact of these parameters on the packaging and shipment of the pieces.

It could be that the optimum way to pack and ship pieces from one of these lines to LNGS is not exactly what the assembly line would like to manage.
For example, during the assembly of the cable rails on the tower a small pack with about 10 screws must enter the cabling-glove-box. On the other end it could be that in Legnaro all the screws needed for CUORE are processed all together. The question is: it is better to pack the screws in groups of ten in Legnaro or it is better to make there a simple, safe and fast packaging with all the screws and then prepare the feeder for the assembly in a more controlled environment like the clean room at LNGS ?

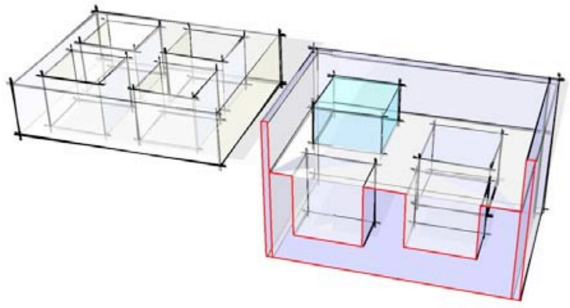
The last solution looks the safest but it means that we have to find a place at LNGS where do to this kind of job. One candidate could be the Borexino Clean room (if still available in 2009-2011) or the Cuoricino clean room if this operation do not interfere with the preparation of the Hall C run.

Even if for copper it would be possible to have all the pieces delivered in packages fully compliant with the assembly specification we already knows that this will not be true for crystals (see next paragraph). Hence the question of finding such qualified space is open and must be solved.

4.1. Crystals

4.1.1. Shipment

Crystals are sent from SICCAS in multiple of four ranging from a minimum of 60 up to a maximum of 72.
Each crystal is individually wrapped in a triple polyethylene bag under vacuum. Each bag carry a bar-code label with an unique ID that identify the crystal in the crystals production database.



To match the post processing needs at LNGS crystals are packed in box of four. The box is a transparent polycarbonate air-tight box for food conservation (Rever-Box) equipped with a valve to pump out air to make vacuum inside (ref. § 12.3) . A pre-shaped anti shock foam shell protect and hold crystals in place inside the box.

The target vacuum level is -900 mbar. Vacuum integrity must be verifiable without touching the box (ref. § 8.2)

Outside the box five barcode labels identify the box itself and the enclosed crystals (ref. § 3)

The shipping container is made up of 15 to 18 x-box. The enclosed documentation report the ID code of the x-boxes and their contents.

4.1.1.1. *Acceptance of the shipment:*

Upon its arrival at LNGS, the outer packaging must be opened and x-boxes and crystals inspected to be accepted or rejected by the assembly.

The action to be taken as result of the inspection depends on the agreement on the subject we have with SICCAS and/or by our internal procedures

About what concern this project the aim of the inspection is to assert the quality of the crystals avoiding that out of spec object enter the assembly chain (or, if they enter, we are aware of their status)

Since at the time of writing the contract has not been signed yet we propose here only our internal procedure. The x-box are inspected one by one but not inside a clean room.

The inspection goes as follow:

- the vacuum level of the x-box is checked by reading an instrument inside the box
- the x-box is opened and the anti shock material removed
- the integrity of the individual wrapping is checked by eye
- the triple wrapped crystals are put inside a new, clean Reber Box (a simple teflon cradle hold the crystals in place, instead of the anti shock material)
- the x-box is closed and the vacuum restored
- the x-box is stored inside the psa
- the old x-box is sent out for cleaning and re-cycled

It could be possible that finding particular failures some extra actions are needed. These occurrences will be discussed while detailing the whole procedure. Standard procedure expose the triple wrapped crystals to air for less then 4 minutes

Possible defect or failure that must be traced and require an action are:

- x-box with lost vacuum:
    - Crystals will be marked as “potentially contaminated”
    - the broken x-box is replaced with a new one
    - crystals are usable as “last resort” if no good spares exist
    - immediate feedback sent to siccas to review packaging procedure or material
    -

- x-box wit lost vacuum + broken outer wrapping in one (or more) crystals
    - All crystals will be marked as “potentially contaminated”
    - broken wrapping crystals are marked “contaminated”

- broken wrapping crystals are… rewrapped (to be discussed)
- immediate feedback sent to siccas to review packaging procedure or material
- the broken x-box is replaced with a new one

- x-box OK but broken outer wrapping found in one (or more) crystals
  - broken wrapping crystals are marked “contaminated”
  - broken wrapping crystals are… (to be discussed)
  - immediate feedback sent to siccas to review packaging procedure or material
  -

- Broken Crystal
  - broken crystals are marked “broken”
  - immediate feedback sent to siccas to review packaging procedure
  -

- All the others are marked in the production database as “ready to use”

After the inspection all boxes are stored inside the Permanent Storage Area (P.S.A.)

4.1.2. *Crystals Storage & Handling at LNGS*

The x-boxes remain inside the PSA until it’s time to glue chip on crystals.
Detail on the PSA facility are given in § 8

Before the assembly crystals must exit/enter the PSA twice: to be glued, to be assembled.

Crystals to be glued exit the PSA in their original x-box.

Before entering the clean room to be glued:

- The x-box is open
- The anti shock foam removed
- The first polyethylene bag removed
- The crystal placed on a clean four fold teflon basket

Inside the clean room the four crystals are put inside their final storage box (the ax-box: assembly crystal box). This box is again a transparent polycarbonate Rever-Like box.
To take into account the different packaging of the crystals before and after gluing (before gluing they are wrapped in two polyethylene bags, after gluing they are naked) the ax-box must foresee two kind of teflon holders to fit at best the size and shape of the wrapped or the naked crystals.
The wrapped crystals holders is a temporary tool used to keep in place the crystals in the ax-box from their entrance into the clean room to the entrance in the antechamber of the gluing glove-box. The wrapped crystal holder can be re-cycled that means that the number of these object to be produced is quite small.

While crystals are going to be glued the “third man” of the gluing team can prepare in the ante chamber the ax-box to receive the naked crystals by replacing the holder.

The amount of naked crystals teflon holder to be produced depends on the maximum number of ax-box will be simultaneously stored in the PSA (ref § 1)

- The crystals exit the gluing glove box within an ax-box with the naked teflon holder.
- Out of the glove Nitrogen is pumped out of the ax-box and vacuum restored.
- The target vacuum level is -900 mbar
- Vacuum integrity must be verifiable without touching the box (ref. § 8.2)

- The ax-box, like that used for shipment, must have labels inside (on the naked teflon holders ?) and outside reporting the ID of the crystals.
- The ax-box is wrapped in a polyethylene bag to keep the external surface clean.
- Crystals to be assembled exit the PSA in their ax-box. The external skin is removed just before the box enter the clean room
- The crystals enter the assembly glove box within the ax-box.

No special care is needed to identify the hard face of a crystal

Taking as reference the schedule in ch.1, the PSA will contain at maximum 508 crystals in 127 box. The minimum number of boxes and accessories needed are:

- 70 ax-box (240 naked glued crystals)
- 112 x-box. (448 wrapped original crystals)
- 70 naked crystals holders + spares
- 4 wrapped crystal holders + spares

4.2. Copper parts for the Towers:

The packaging of copper parts proposed in the next paragraphs it's the current best match (in terms of protection from re-contamination) between the capabilities to clean and handle safely the pieces at LNL and the logistic on the assembly side.

4.2.1. Acceptance of the shipment:

Upon its arrival at LNGS, the outer packaging must be opened and the individual boxes inspected to be accepted or rejected by the assembly.
The action to be taken as result of the inspection depends on the agreement on the subject we have with LNL or by our internal procedures
The inspection must check:

- vacuum level (if applicable) of the box
- integrity of the individual wrapping

4.2.2. Top-Bottom Plates

There are two kinds of end-plate: Top EPT and bottom EPB. One tower is ended by one top plate and one bottom plate. Bottom plates are fixed by screws while top plates are fixed to the detector support plate by pillars.
The total number of EPT and EBP to be produced is:

End Plates production

kind	pcs	spare	total
EPT	19	1	20
EPB	19	1	20

End Plates are cleaned in groups of 5:

End Plates cleaning (magn. cycles)

kind	mc
EPT	4
EPB	4

One magnetron run last one week and end plates will be packed and shipped as soon as they are cleaned (one shipment per week). The end plates last cleaning takes a total of 8 weeks.
Pieces are packed singly and shipped in bunch of 5 inside a box (EP-box).

PACKAGE: *** TO BE DISCUSSED ******

Once at LNGS the EP-box are stored in the PSA as they are.

About the production database: All EP packages must have a bar code label with the copper production ID (the same number applies to all plates belonging the same magnetron run).

We have a total of 8 shipping unit (one per week)

4.2.3. Frames

There are four kinds of frames: middle type A (MA), middle type B (MB), Top (FT) and Bottom (FB). One tower is made by six MA, six MB one FT, one FB for a total of 14.
The total number of frames to be produced is:

Frame production

kind	pcs	spare	total
MA	114	24	138
MB	114	24	138
FT	19	5	24
FB	19	5	24

Frames are cleaned in groups of six:

Frames cleaning (magnetron cycles)

kind	mc
MA	23
MB	23
FT	4
FB	4

One magnetron run last one week and frames will be packed and shipped as soon as they are cleaned (one shipment per week). The frames last cleaning takes a total of 54 weeks.
To guarantee a smooth feed to the assembly line the frames' cleaning must occur in turns following the scheme shown at the end of the paragraph.
Frames are packed singly and shipped in bunch of six inside a box (F-box), with F= MA, MB, FT, FB).
The mechanical stress induced on a frame by the polyethylene bag shrinking while making vacuum could be not negligible and, in any case cannot taken under control. This can be avoided by enclosing the frame in a rigid shell like the IKEA food box Illustrated in § 12.1.
To have the frames always in contact with clean material the shell is equipped with a teflon plate with holders (for example four holes that copy the shape of the tips in the corner of the frame). To keep the frame firmly in place, if necessary, a teflon spacer can be used to fill the gap between the top of the frames and the shell cover.
The shell is not air tight but , on the contrary have holes to help the air to come out. The shell is then wrapped in a polyethylene bag with the vacuum done as usual.
The shell is double wrapped.
Groups of six shell are then double wrapped together in two other bags to form a shipping unit. FT and FB that enter the assembly line in groups of two could be wrapped in groups of two instead of six to improve the optimization of handling and storage at the PSA.
This shipping units do not fit any rever like box but the same results can be obtained by putting them in any plastic box that fits, wrapping the box inside a bag and making vacuum. Again this box must have holes to let the air flush out of the box while pumping.

Once at LNGS the F-box are stored in the PSA as they are. For the assembly one MA-box, one MB box, one FT-Box and one FB box must move to interlock area of the clean room. For

the MA and MB box all skins but the last two are removed inside the interlock area and 6 + 6 individually double wrapped shells enter the clean room.
FB and FT box are opened in the same way but only one per kind will enter the clean room with the external shell skin removed. The other are re-packed and put back in place in the PSA.

About the production database: All shells must have on top a bar code label with the copper production ID (the same number applies to all frames belonging the same magnetron run).

We have a total of 54 shipping unit (one per week)
We have a total of 324 IKEA shells (estimated cost = 645 euro)
We have a total of 324 teflon holder
We have a total of 324 teflon spacers (if needed)

If these number can be less is discussed at the end of the chapter when I try to synchronize the production schedule with the assembly schedule.

small parts used to protect some surfaces from the cleaning tools must not be removed[9]

4.2.4. Towers' Pillars:

There are two kinds of pillars: Female-Female (PFF) and Male-Female (PMF).
A tower is made by 4 PFF and 48 PFM for a total of 52.
The total number of pillars to be produced is:

Pillars production

kind	pcs	spare	total
PFF	76	24	100
PFM	912	188	1100

Pillars are cleaned in groups of 20.

Pillars cleaning (magnetron cycles)

kind	mc
PFF	5
PFM	55

One magnetron run last one week and pillars will be packed and shipped as soon as they are cleaned (one shipment per week). The pillars last cleaning takes a total of 60 weeks.

To guarantee a smooth feed to the assembly line the cleaning of pillars must occur in turns following the scheme shown at the end of the paragraph.
Pillars are individually packed in sets of 4 and shipped in bunch of 20 inside a box (P-box), with P= PFF, PFM).

Vacuum packed bags should not induce any mechanical problem like it could be for frames.
Sets of 4 pillars are immediately triple wrapped in polyethylene bags under vacuum. Groups of five packets inside a rever-box form a shipping unit.

Once at LNGS the P-box are stored in the PSA as they are. For the assembly of one tower one packet of PFF and 12 packets of PFM are needed. Actually they are distributed in the PSA over at least one PFF-box and three PFM-box.

[9] This rule must be decided when we will know where and how many these pieces will be

When needed all these P-boxes move to the interlock area of the clean room. The P-Boxes are opened and the external skin of one PFF packet and 12 PFM packets removed. The resulting clean packets enter the clean room. All the others are kept inside the their box. Once this operation is over the PFF and PFM rever-boxes are closed, the vacuum restored and put back in the PSA.

About the production database: The inner wrapping bags of each packet and the cover of the P-box must be bar-code labeled with the pillars production ID (the same number applies to all the pillars belonging the same magnetron run).

We have a total of 65 shipping unit (one per week)
We have a total of 65 rever-like box

If these number can be less is discussed at the end of the chapter when I try to synchronize the production schedule with the assembly schedule.

small parts used to protect some surfaces from the cleaning tools must not be removed[10]

4.2.5. Cable rails

Cable rails are made of two sections (CRS top and bottom) and two covers (CRC) + one joint (CRJ).
A tower mounts two cable rails for a total of 4 sections and 4 covers and two joints.
The total number of pieces to be produced is:

Cable rails production

kind	pcs	spare	total
CRS	76	8	84
CRC	76	8	84
CRJ	38	4	42

Cable rails sections or covers are cleaned in groups of 6. Joints are cleaned in groups of 14[11]

CR cleaning (magnetron cycles)

kind	mc
CRS	14
CRC	14
CRJ	3

One magnetron run last one week and cable rail pieces will be packed and shipped as soon as they are cleaned (one shipment per run). The cable rail last cleaning takes a total of 31 weeks.
To preserve the bending angle of the wings (see cable rail drawing in §13) cable rails are put over a clean PTFE holder replicating their shape. Rails are kept in place by a couple of nylon screws.

[10] This rule must be decided when we will know where and how many these pieces will be
[11] to be confirmed

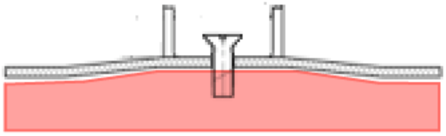


Figure 8: shape of the cable rail teflon holder

Rail holders and screws must be cleaned in advance (LNGS) and sent inside clean packs to LNL Holders are shorter then cable rail segment leaving the joint side free. During cabling assembly cable rails are kept on their holders (more on that in the cable rod assembly paragraph)

4.2.6. Cabled rods

Cable rails are assembled and cabled in a separate process. The final piece, the "cabled rod" is stored in clean room and not in the PSA.

4.2.7. Copper shield (CUORE0)

To match the post processing needs at LNGS Copper shield for CUORE-0 must be packed singly in vacuum packed bag and shipped all together in a cs-box.

4.2.8. Screws

There are four kinds of screws (different size and/or different head shape):

- Slotted flat head to fix the cabled rod to the frames through the cover (FHC)
- Slotted flat head to join cable rail segments (FHS)
- Slotted pan head to fix cable rod to the frames through the segments (PHS)
- Slotted pan head to fix top and bottom frames (PHF)

A tower is made by 14 FHC + 14 PHS + 8 FHS (two cabled rods) and 8 PHF (Top Bottom frames) for a total of 44 screws.

The total number of screws to be produced is:

Screw production

kind	pcs	spare	total
FHC	266	94	360
FHS	152	48	200
PHS	266	94	360
PHF	152	48	200

Screws are chemical processed in groups of 40.

Screw cleaning (chemical bath)

kind	cb
FHC	9
FHS	5
PHS	9
PHF	5

One chemical bath last one day (to be confirmed). Screws will be packed and shipped as soon as they are cleaned (one shipment per chemical cycle). The screws last cleaning takes a total of 28 days.

To guarantee a smooth feed to the assembly line the screws' cleaning must occur in turns following the scheme shown at the end of the paragraph.
Out of the bath screws are packed in sets of 40 (a full chemical bath) in a triple polyethylene bags wrapping under vacuum and immediately shipped to LNGS in a rever-box (H-box), with H= FHC, FHS, PHS, PHF).

Once at LNGS the H-box are stored in the PSA as they are.

PHF screws must be in clean room at the time of a mechanical assembly shift. How to handle this package must be understood (The package contains more screws then needed)

FHC, PHS screws must be in clean room at the time of cabling assembly shift. How to handle this package must be understood (The package contains more screws then needed)

FHS screws must be in clean room at the time of a pre-cabling turn. How to handle this package must be understood (The package contains more screws then needed)

About the production database: The inner wrapping bags of each packet and the cover of the H-box must be bar-code labeled with the screws production ID (the same number applies to all the screws belonging the same chemical bath).

We have a total of 28 shipping unit (one per chemical process)
We have a total of 28 rever-like box

4.2.9. Copper QC on Shipment and Storage

Like for any other object stored in the PSA the main QC duty is to check daily the integrity of the box (vacuum level). Whenever it is possible wEvery time it is possible to have a transparent box this check is done by looking at the status of the pressure sensor inside the box.
(to be continued)

4.3. PTFE

Very preliminary inventory of PTFE pieces. Cannot be completed until all copper shipment, handling and storage issues have been defined.

- **detector components**
  - Assembly Holders (3 shapes)
- **Ancillary parts for storage & handling**
  - Wrapped crystals cradle
  - Naked crystals holder
  - Frame shell plate
  - Cable rail holders
  - bobby pins
  - nylon screws
  - Teflon basket
- **Tower assembly**
  - meck glove box turning table
  - ...

4.3.1. Acceptance of the shipment

4.3.2. Assembly holders

4.3.3. Storage crystals holders (naked and wrapped)

4.3.4. Frame shell plate

4.3.5. Cable rails set (cable rail holder, bobby pins, nylon screws)

4.4. Heathers & Thermistors (empty)

4.4.1. Acceptance of the shipment

4.5. Cables and connectors

4.5.1. Acceptance of the shipment

No info are available on cable/connectors shipment and QC requirements

4.5.2. Cables

Cable strips are cut at size after production , before cleaning.
All strips have the same length.
Each strip carries four bonding pads feeding both heaters and thermistors of 4 crystals.
A cabled rod is made of seven strips with seven different pads' patterns
The seven strips needed to cable a rod (a strip set) are cleaned in the same chemical cycle.
A tower is made by two cabled rod for a total of 14 strips.

The total number of strips to be produced is:

Strips production

kind	pcs	spare	total
ST1	38	10	48
ST2	38	10	48
ST3	38	10	48
ST4	38	10	48
ST5	38	10	48
ST6	38	10	48
ST7	38	10	48

Strips are chemical processed in groups of 7 (strip set).

Strips cleaning (chemical bath)

kind	cb
Strip set (st1+st2+...+st7)	48

One chemical cycle (including packing and shipping) last one day (to be confirmed). Strips will be packed and sent to the PSA as soon as they are cleaned (one shipment per chemical cycle). The strips last cleaning takes a total of 48 days.

Out of the bath the strips are packed one on top of the other in the right sequence to form a strip set "ready to mount". The first 80 cm of the strips (those that go straight inside the cable rail) are kept flat while the extra length is compacted in a roller shape fixed by teflon bobby pins (grips). The strip set is then packed in a transparent box (ST_Box)) triple wrapped in a polyethylene bags under vacuum.

ST-box are custom made and have the size of 100x10x20 cm.

ST-Box enter the clean room at the time of a cabling assembly shift. The outer skin is removed in the clean room interlock area.

About the production database: The inner wrapping bags of each packet and the cover of the ST-box must be bar-code labeled with the strips production ID (the same number applies to all the strips belonging the same chemical bath).

We have a total of 48 shipping unit (one per chemical process)
We have a total of 48 ST-Box

4.6. Consumables (scotch, chemical etc..)

4.6.1. Acceptance of the shipment

4.7. Assembled Towers (empty)

4.7.1. Tower QC on Storage

4.8. Other Copper parts to be cleaned in Legnaro:

Parts listed here are components to be installed on the cryostat, like the copper tiles used to shield the surface of the mixing chamber facing the detector, or other parts to be mounted on the assembled towers or to mechanically couple the towers to the support plate.

4.8.1. Acceptance of the shipment:

Upon its arrival at LNGS, the outer packaging must be opened and the individual boxes inspected to be accepted or rejected by the assembly.
The action to be taken as result of the inspection depends on the agreement on the subject we have with LNL or by our internal procedures
The inspection must check:

- vacuum level (if applicable) of the box
- integrity of the individual wrapping

4.8.2. Mixing Chamber shield

5 mm thick tiles cover the inner surface of the mixing chamber facing the naked towers. There is just one kinds of tile: TL.
A complete shielding is made by two rows of 25 tiles approx 120x400x5 mm for a total of 50 tiles
The total number of tiles to be produced is:

Tiles production

kind	pcs	spare	total
TL	50	4	54

Tiles are cleaned in groups of XX:

Tiles cleaning (magnetron cycles)

kind	mc
TL	XX

One magnetron run last one week and tiles will be packed and shipped as soon as they are cleaned (one shipment per week). The tiles last cleaning takes a total of XX weeks.
Tiles are packed singly and shipped in bunch of XX inside a box (TL-box).

PACKAGE: *** TO BE DISCUSSED ******

Once at LNGS the TL-box are stored in the PSA as they are.

About the production database: All tiles packages must have a bar code label with the copper production ID (the same number applies to all tiles belonging the same magnetron run).

We have a total of XX shipping unit (one per week)

5. Overview of the organization of the activities at LNGS

The organization of the work at LNGS strictly depends on the time schedule of the individual production/cleaning chains (TeO2, Cu, PTFE). how they match in time and their coordination.
The main impact being on storage space and assembly strategy.
I show here two scenarios taking as driving schedule the crystal production road map that is, at the time of writing, almost fixed.
Crystals production and cleaning will last around 32 months with a constant production rate of 30 pieces per months, a bi monthly delivery, with the possibility of a small increase in the yield at the end of the production. How much this increase should be and when it should start to optimize the assembly chain is part of the exercise and will be discussed later.
Working on both scenarios I put as goals:

- To have the last tower assembled within no more then two months after the delivery of the last component at LNGS
- Minimize the number of individual pieces (frames, crystals, etc..) stored in the P.S.A.

Taking into account also the needs to

- Have time and resources to maintain a complete control over pieces in stock and their storage conditions
- Have time and resources to have the complete control of any post-delivery operation (like re-packaging if it is needed)
- try to maintain as high as possible the attention of operators on the action currently underway avoiding as much as possible jobs in parallel in the same place.
- minimize the load on the clean room

5.1. *Synchronized Production chains*

This is the case where towers assembly can start, more or less, when half of the crystals have been produced. The main advantage of this solution is that the P.S.A. space (Permanent Storage Area) is kept to the minimum and many items can be recycled saving time (those needed to make many ancillary parts of the storage system) and money but at the price to have well planned and synchronized copper, teflon, cables, heathers/ thermistors and crystal production chains. In the following such a coordination is discussed only for copper components and crystals.
Once the critical mass have been reached assembly can start as a periodic sequence of processes leading to the assembly of four towers.
With the information currently available on the time needed to clean each flavor of copper pieces (see previous chapter) the assembly of four towers last less then the time needed to produce their components. A typical "assembly round" can take up to 3 months: one (more or less) for gluing and the pre-cabling of cable roads, one (more or less) for tools cleaning and maintenance, one (exactly) for tower assembly.

In the next table and plot you find an example of how thing could be arranged.

Doing this exercise the following assumptions have been done:

- INFN production goes as stated in the current DRAFT of the contract
- USA production will follow INFN production at the same rate. A small increase in the amount of crystals delivered (70 instead of 60 every 2 months) is foreseen near the end of the production to force its completion on March 10, 2011
- Towers are assembled in group of four
- A “slow” startup (2 towers instead of 4) is foreseen to have time to face any last-minute problem should occurs
- A quite reasonable gluing rate is assumed (max 10 crystals per day)
- the time between the last crystal arrival and the last tower ready have been minimized.

As shown in the table the first delivery for CUORE is foreseen in Nov 2008. Nothing happen at LNGS (except for crystals storage monitoring and maintenance) up to January 2010 when clean room activities start with the gluing of the first batch of crystals. Actually gluing could start even before if some extra time is needed to tune up the system.

At that moment at LNGS there will be the maximum occupancy of the storage area with 508 crystals: 350 as packed at SICCAS and 158 re-packed after gluing.

The assembly cycle is repeated 6 times for a total of 13 months. The last cycle is shorter both for gluing (only 70 crystals to glue and re-pack) and for assembly (two towers). The last tower should hence be ready for mid May 2011.

Copper and Teflon production and delivery should follow this scheme having all and ONLY (again to minimize P.S.A. occupancy) the pieces needed to assemble 4 towers delivered two months before an assembly shift starts.

Some items with small impact on storage space and logistics, like screws, could be produced all at once (if it is more convenient for Legnaro) and delivered in one bunch at the end of 2009.

Towers will be assembled one per week in turns of 4 weeks every 3 months. The best match between PSA organization and assembly chain would be the case where every flavor is stored in a box containing exactly the number of pieces needed to assembly one tower.

A set of boxes with all the pieces needed to assembly one tower is called a Tower Kit.

As seen in the previous paragraphs it is not always possible to arrange the shipments in tower kits mostly because in many cases it is better to skip off shipping package optimization then to risk recontamination introducing much more pieces manipulations to arrange them in towers kits compliant boxes.

CUORE ASSEMBLY SCHEDULE (based on crystal delivery al LNGS)								
Date	XI delivered	XI produced	XI in assembly	XI in gluing station	stock of clean crystals	stock of XI in towers	stock of glued crystals	total XI storage
pre-prod	60	60	52	52	60	52	0	60
		60			8	52	0	8
		60			8	52	0	8
20-Nov-08	60	120			68	52	0	68
					68	52	0	68
19-Jan-09	60	180			128	52	0	128
					128	52	0	128
20-Mar-09	60	240			188	52	0	188
					188	52	0	188
19-May-09	60	300			248	52	0	248
					248	52	0	248
18-Jul-09	60	360			308	52		308
					308	52	0	308
16-Sep-09	60	420			368	52	0	368
					368	52	0	368
15-Nov-09	60	480			428	52	0	428
	20				448	52	0	448
14-Jan-10	60	560		158	350	210	158	508
15-Feb-10			104		350	210	54	404
15-Mar-10	60	620			410	210	54	464
15-Apr-10				190	220	400	244	464
14-May-10	70	690	156		290	400	88	378
15-Jun-10					290	400	88	378
13-Jul-10	70	760		190	170	590	278	448
15-Aug-10			208		170	590	70	240
11-Sep-10	70	830			240	590	70	310
15-Oct-10				190	50	780	260	310
10-Nov-10	70	900	208		120	780	52	172
15-Dec-10					120	780	52	172
9-Jan-11	70	970		190	0	970	242	242
15-Feb-11			208		0	970	34	34
10-Mar-11	70	1040			70	970	34	104
15-Apr-11				70	0	1040	104	104
9-May-11		1040	104		0	1040	0	0
total	1040		1040	1040				

Table 2 : Example of schedule for CUORE assembly. Absolute dates could be wrong by one or two months.

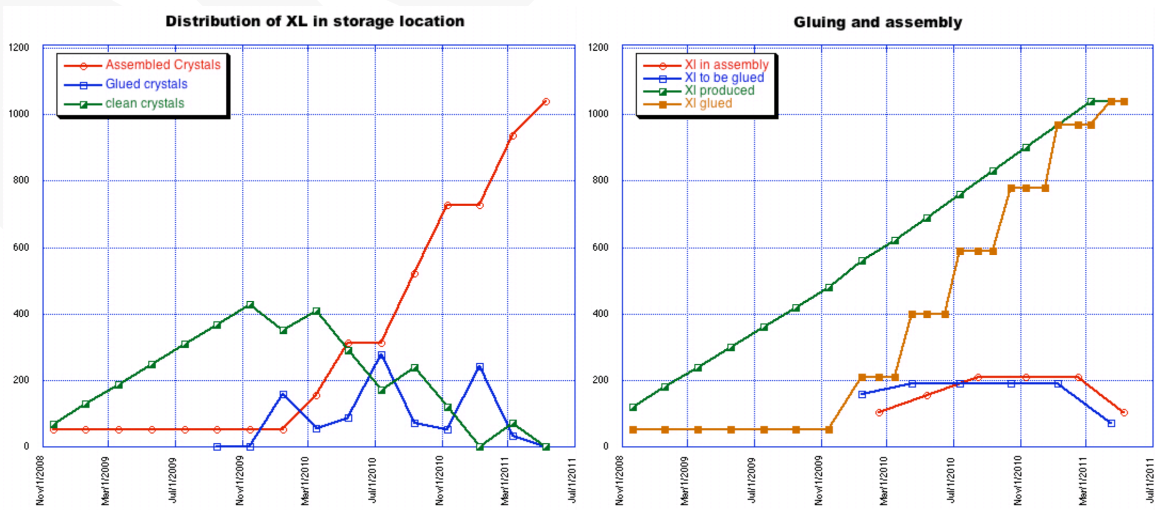


Figure 9: Crystals throughput in the P.S.A. (left) and crystals gluing and assembly (right)

Nevertheless even if embedded in several boxes all the pieces needed to assembly a tower must be in the PSA exactly when needed and some optimizations are still possible.

The assumptions done with copper production are:

- It takes one week (5 working days) to prepare, start, execute a magnetron run, pack the pieces and send the box to LNGS
- One shipping box per week arrive at LNGS
- On average the real working weeks in one year are 47 (holydays included)
- I have the bad attitude to have a full month holydays during summer. Many others do the same too. Usually in August.
- The total number of magnetron run is around 150 (copper for the Towers only)
- Only one month is allowed for technical stop. Note: not one month per year. Just one. In table 3 this is taken into account anticipating the completion of the cleaning by one month.
- Pieces, like screws, that do not use the magnetron are processed in parallel. No special time slots are foreseen for these activities.
- Any pieces that must be cleaned with the magnetron, other then those mentioned here, must be processed before or after the period allotted for the towers. In other words there is no time sharing between tower pieces cleaning and cleaning of other parts.

The next table gives a summary of all the copper pieces to be processed with plasma cleaning:

Parts	code	one tower	CUORE		spare	cleaning bunch	magn. Run	total to process
Frame A	MA	6	114		24	6	23	**138**
Frame B	MB	6	114		24	6	23	**138**
Frame Top	FT	1	19		5	6	4	**24**
Frame Bottom	FB	1	19		5	6	4	**24**
Pillar FF	PFF	4	76		24	20	5	**100**
Pillars FM	PFM	48	912		188	20	55	**1100**
Cable rails	CRS	4	76		8	6	14	**84**
	CRC	4	76		8	6	14	**84**
	CRJ	2	38		4	14	3	**42**
EndPlate	EP	2	38		2	5	8	**40**
	Towers Total						**153**	**1774**
Cable rails			40		2	6	7	**42**
Cable rails joint								
bottom shield (skirt)			24		6	6	5	**30**
Tiles			50		4	6	9	**54**
Pillars		4	76		4	20	4	**80**
	Cuore Total						**25**	**206**
	Total						**178**	**1980**

Table 3 summary of copper pieces to be plasma cleaned in Legnaro

To feed the assembly chain in the right way the magnetron runs must proceed in turns. An example is shown in the next table where in red are marked the target assembly months quoted in table 2.

The philosophy adopted making this table is: first start the procedure with something easy (PFM) , run it continuously for 4 months and tune up the system. Next face the worst pieces (if something must go wrong it is better to know it as soon as possible) CRC, CRS. CRJ. Finally start the routine production alternating the pieces as needed by PSA.

With the above mentioned definition of one working year and to be compatible with the crystal production schedule cleaning must start at full speed the first week of February 2008.

This is NOT the problem since, as I mentioned before, the time quoted to accomplish a magnetron run must be taken as the current best guess of Enzo Palmieri. It could be less by far.

The aim of the exercise is to show how things could work if the two main production chains have compatible time schedules and an high degree of synchronization.

Months	# wks	w1	w2	w3	w4	w5
February-08	4	PFM	PFM	PFM	PFM	
March-08	5	PFM	PFM	PFM	PFM	PFM
April-08	4	PFM	PFM	PFM	PFM	
May-08	4	PFM	PFM	PFM	PFM	
June-08	5	CRC	CRC	CRC	CRC	CRC
July-08	4	CRC	CRC	CRC	CRC	
August-08	4					
September-08	5	CRC	CRC	CRC	CRC	CRC
October-08	4	CRS	CRS	CRS	CRS	
November-08	4	CRS	CRS	CRS	CRS	
December-08	4	CRS	CRS	CRS	CRS	
January-09	4	CRS	CRS	CRJ	CRJ	
February-09	4	CRJ	PFM	PFM	PFM	
March-09	5	PFM	PFM	PFM	PFM	PFM
April-09	4	PFM	PFM	PFM	PFM	
May-09	4	PFM	PFM	PFM	PFM	
June-09	5	PFM	PFM	PFM	PFM	PFM
July-09	4	PFM	PFM	PFM	PFM	
August-09	4					
September-09	5	PFM	PFM	PFM	PFM	PFM
October-09	4	PFM	PFF	PFF	PFF	
November-09	4	FT	FT	FB	FB	
December-09	4	MA	MA	MA	MA	
January-10	4	MB	MB	MB	MB	
February-10	4	MB	MB	MB	PFM	
March-10	5	PFM	PFM	PFM	MA	MA
April-10	4	MA	MA	MB	MB	
May-10	4	MB	MB	PFM	PFM	
June-10	5	PFM	PFM	MA	MA	MA
July-10	4	MA	MB	MB	MB	
August-10	4					
September-10	5	MB	PFF	PFF	MA	MA
October-10	4	MA	MA	MA	MB	
November-10	4	MB	MB	MB	FT	
December-10	4	FT	FB	FB	MA	
January-11	4	MA	MA	MA	MB	
February-11	4	MB	MB	MB	PFM	
March-11	5	PFM	PFM	PFM	MA	MA
April-11	4					
May-11	4					

Table 4 copper magnetron runs schedule

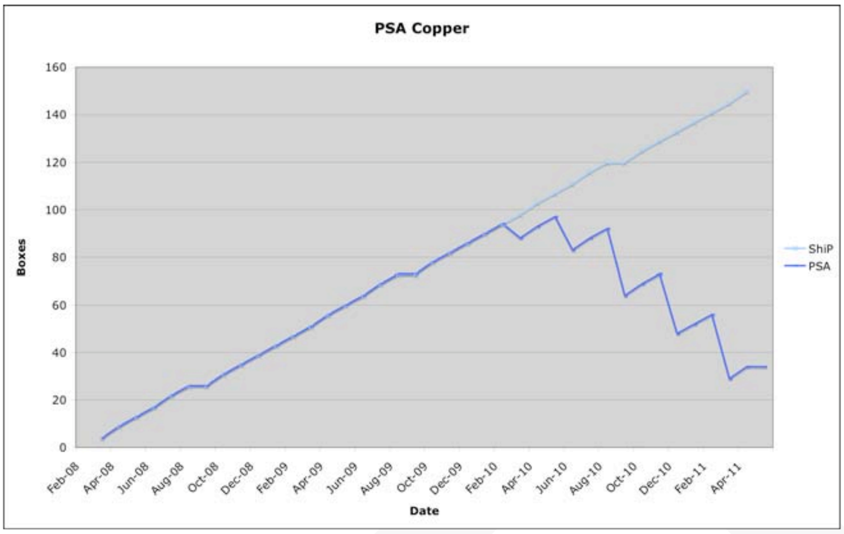


Figure 10: copper occupancy inside the P.S.A.

Figure 11 shows the occupancy (in number of boxes) of the PSA during this period. As you can see the maximum number of boxes in the PSA (towers' copper only) is 100.

5.2. Independent Production chains

If no synchronization among production chains it is possible than most likely the towers' assembly will start only when all the pieces are in and will proceed as a 19 consecutive weeks job. Consider also that in this case it is not possible to state when, after the delivery of the last piece, the last tower will be assembled since some processes like pre-cabling of cable rails and crystals gluing are done in the same clean room and are incompatible with towers' assembly.

For this reason even if a complete coordination among production chains it is not possible some optimization are worth to be considered both for CUORE (for example avoiding that cable rails come last) and CUORE0 (for example by anticipating the cleaning of the cryostat cop

Table 5 : yellow: CUORE0 production weeks, red: cryostat copper pieces cleaning, orange CUORE towers copper cleaning, green crystals shipment.

week Months	1	2	3	4	5	1	2	3	4	5		
February-08												
March-08												
April-08												
May-08												co
June-08	1	2	3	4	5							co
July-08	4	5	6	7								
August-08												
September-08	9	10	11	12	13							
October-08	13	14	15									cr
November-08											60	
December-08						1	2	3	4			
January-09						5	6	7	8		120	
February-09						9	10	11	12			
March-09						13	14	15	16	17	180	
April-09						18	19	20	21			
May-09						22	23	24	25		240	
June-09						26	27	28	29	30		
July-09						31	32	33	34		300	
August-09												
September-09						35	36	37	38	39	360	
October-09						40	41	42	43			
November-09						44	45	46	47		420	
December-09						48	49	50	51			
January-10						52	53	54	55		480	
February-10						56	57	58	59			
March-10						60	61	62	63	64	540	
April-10						65	66	67	68			
May-10						69	70	71	72		600	
June-10						73	74	75	76	77		
July-10						78	79	80	81		660	
August-10												
September-10						82	83	84	85	86	720	
October-10						87	88	89	90			
November-10						91	92	93	94		780	
December-10						95	96	97	98			
January-11						99	100	101	102		840	
February-11						103	104	105	106			
March-11						107	108	109	110	111	900	
April-11						112	113	114	115			
May-11						116	117	118	119		960	
June-11						120	121	122	123	124		
July-11						125	126	127	128		1020	
August-11												
September-11						129	130	131	132	133	1040	
October-11						134	135	136	137			
November-11						138	139	140	141			
December-11						142	143	144	145			
January-12						146	147	148	149			
February-12						150	151	152	153			
March-12						154	155	156	157	158		
April-12						159	160	161	162			
May-12						163	164	165	166			
June-12						167	168	169	170	171		
July-12						172	173	174	175			
August-12												
September-12						176	177	178				
October-12												
November-12	cuore 0										TeO2	
December-12												

per pieces to maximize the time interval between the construction of CUORE0 and the start of the production and cleaning of the CUORE towers copper parts. In this way, the total cleaning time would remain the same but in the event of a negative performance of CUORE0 most of the cleaning of frames and parts of CUORE would not been started yet and any revised procedure could be applied without wasting time).

The last sentence is shown in table 5. With the same consideration on time needed to clean copper pieces done before a total of 178 weeks are needed to accomplish the task. Here the first 25 are dedicated to clean non towers copper components (tiles etc..) delaying the startup of CUORE towers pieces cleaning by fine months. CUORE towers assembly could start some months before the end of copper delivery IF cleaning sequence is well planned.

It's obvious that this figure could change a lot once a realistic estimate, pieces by pieces, of the cleaning time will be available making this argument weaker or not relevant at all.

6. Cleaning facilities at LNGS

Any of the boxes, holders etc... used for shipments and pieces' handling at the PSA must be bought in advance, cleaned and sent to the production sites (SICCAS and LNL).

Up to now I count 1215 pieces to handle and clean.

After cleaning (probably a simple chemical process with soap and weak acids) pieces must be vacuum packed in a single (or double) polyethylene bag and sent to their destination.

Not defined yet:

- where to do the job
- the consumables needed
- the tools needed (basins of special size like those needed for cable strip cleaning etc...)

7. The clean room

Even if all the assembly operations will be done inside a glove box and an accurate packaging would avoid any contact of the pieces with the external environment it is advisable to run these chain inside a clean environment.

One reason, out of many, is that the glove-boxes like all the other tools used to assemble the detectors, must be "clean tools" and hence any operation, like any standard maintenance work, should be done in a clean environment.

The clean room facility should have a "clean room operation manger (CROP)", different from any people involved in the assembly, with the responsibility to ensure the functionality and the integrity of the facility and its correct usage by the users.

Anything entering the clean room and the way it enter should be under the CROP control.

A raw sketch of how the assembly tools could be arranged inside a clean room (in the drawing the dimensions of the room are those of the Borexino facility) is shown in picture 6.

The tower garage (8) (more on that in the next chapter) is placed somewhere and fixed to the floor. Around three sides of the garage a step (7) brings the operators at the right height with respect to the working plane.

Trails (or shuttles) from 1 to 4 are those carrying the glove boxes to be coupled with the garage.

Tables 5 and 6 host the glove boxes used to pre-cable the cable rails and glue the chips onto the crystals.

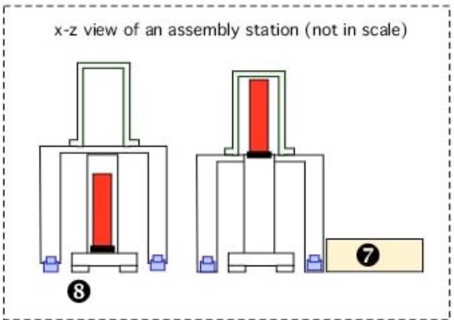


Figure 1**Error! Reference source not found.** shows (not in scale) how the trail docks to the garage.

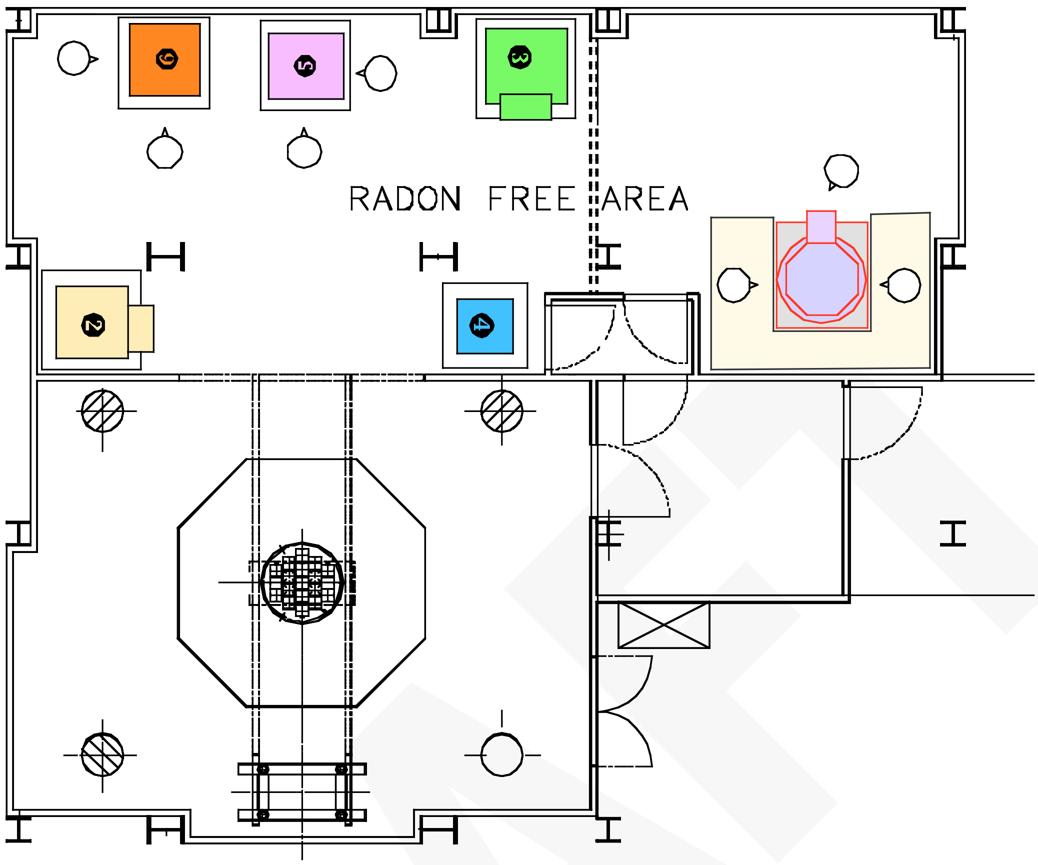


Figure 11: A possible arrangement of the assembly tools inside CUORE clean room

Figure 12:A possible arrangement of the assembly tools inside Borexino clean room

8. The permanent storage area (PSA)

Polycarbonate (or any plastic) is permeable to Radon with a diffusion coefficient of the order (worst case) of $K=1x10^{-6}$ cm^2 sec^{-1}. Taking as reference the schedule shown in the previous chapter the time elapsing between shipment and assembly can be as long as 16 months.

The PSA must provide:

- protection against long term (order of years) radon diffusion induced re-contamination for all the critical components.
- protection against short term (order of hours) radon direct induced re-contamination in case of failure of the first level shield (broken wrapping, vacuum lost in the box etc…)

Both features can be accomplished by putting all the pieces, within their shipping box, inside pure (evaporated) Nitrogen flushed, air tight, closets stacked in the PSA.

Moreover the PSA is used to

- provide an almost clean area (dust free) suitable for
  - receive and check upon arrival shipped stuff
  - pieces repackaging (when needed by assembly procedures)
  - storage boxes QC
  - storage boxes and wrapping maintenance

The proximity of a clean room is a valuable support in case of major works on storage boxes

A preliminary evaluation of the number and kind of pieces to be stored is reported here:

Part Name	D (LxWxH)	Stackable	Probe	Num	Vtot(mc)
(A)X-BOX	20x25x12	no	yes	260	1,560
FT-Box (IKEA)	17x17x3	yes	no	26	0,023
FB-Box (IKEA)	17x17x3	yes	no	26	0,023
MA-Box (IKEA)	17x17x6	yes	no	144	0,125
MB-Box (IKEA)	17x17x6	yes	no	144	0,125
PF(F/M)-Box	20x13x12	no	yes	67	0,210
CR-Box	40x10x3	yes	yes	32	0,039
H-Box	20x13x12	no	yes	29	0,090
ST-Box	100x10x20	yes	yes	50	1,000
End plates	…	…	…	10	…
Teflon Hold.	…	…	…	…	…

Table 6: towers components to be stored into the PSA. For some items packaging has not chosen yet

Part Name	D (LxWxH)	Stackable	Probe	Num	Vtot(mc)
pillars	…	…	…	…	…
bottom shield skirt	…	…	…	…	…
cable rails	…	…	…	…	…
copper tiles	…	…	…	…	…

Table 7: cryostat components to be stored into the PSA. For some items packaging has not chosen yet

As expected the maximum storage space is taken by (A)X-Box (crystals). Tables do not include spare boxes kept in stock for box swapping (for example naked and glued crystals) or to replace broken or defective boxes.

In this table the number of (A)X-Boxes quoted take into account the complete CUORE crystal production .

In the following, by evaluating the space and the infrastructures needed by the PSA I consider the case that all the crystals and all other parts of the detector must be simultaneously stored into the PSA before the assembly starts.

This imply a strong constraint only on the total space required by the PSA while with a modular approach the storage system (infrastructure and closets) can grow as needed, up to fill the PSA, by following the real-life delivery and assembly program.

8.1. Location

A convenient choice for the location of the PSA could be the CUORICINO II[nd] floor near the CUORICINO clean room. The following drawing shows a possible arrangement and the occupancy of the closets need to store the full crystals production.

Since the stairs are quite steep to help move boxes in and out the PSA a lift should be available to carry the shipping boxes from the ground floor up. The large double door on the west wall could be the access point. The possibility of a bridge connecting the PSA and the CUORE clean room is definitively excluded.

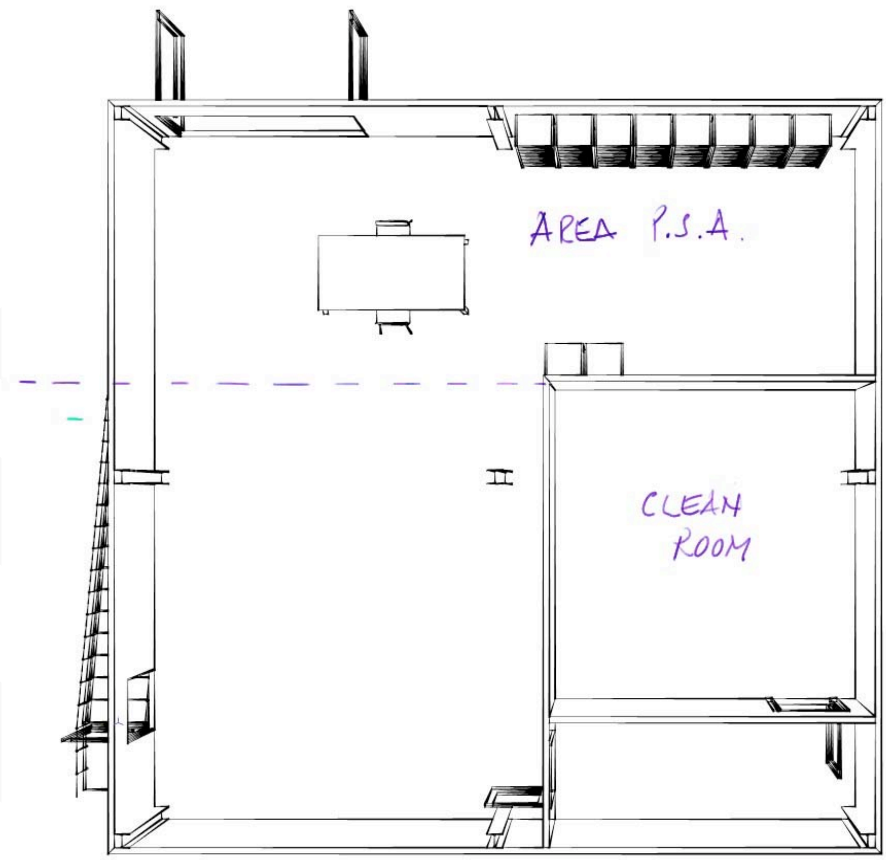


Figure 13: Top view of the cuoricino 2nd floor. The PSA space shown is filled (only) with 20 closets housing the full crystals production.

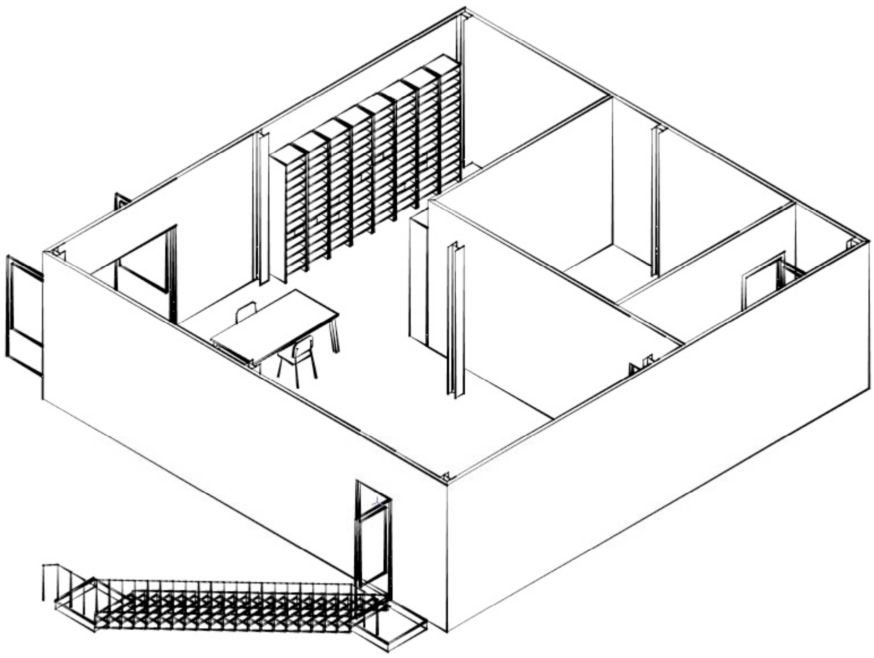


Figure 14: iso metric view of the P.S.A. in cuoricino

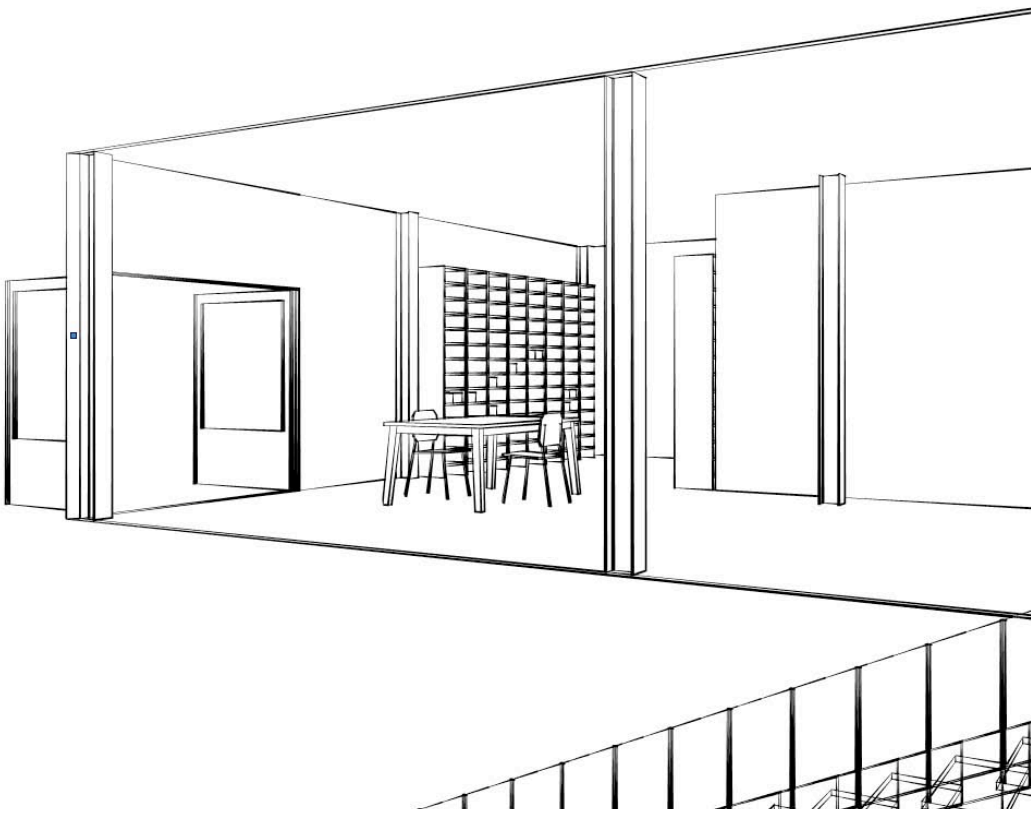


Figure 15: another nice picture of the P.S.A.

Advantages of the Cuoricino choice are that it is a scalable solution and, on emergency, the CUORICINO clean room can be used.

Scalability or, better, how our occupancy of this space grow with time could be taken into account discussing the destination of this area with the LNGS space committee . At thye beginning (within a couple of months). At the beginning (within a couple of months) we need only a quite small area since we have to put in place just a couple of closets to accommodate the first crystals delivery and the cuore0 copper parts. This area cold be half the corridor on the top/right side of the room (that under the P.S.A. written in Figure 13. This area could be delimited and made dust-free with a simple polyethylene panels floor hanging from the roof.

At later time, when more space is needed, panels can be moved first to close the full corridor (let's say by prolongating the clean room wall up) and finally following the dotted line drown in Figure 13.

Another choice could be to use the BOREXINO clean room both for cuore0 assembly and as final P.S.A. . The clear advantage is that the P.S.A. would be inside a clean room. The cont. are that this make more boring the daily check of the status of the parts stored (you have to enter a clean room be mindful of all the rules that apply in this case) unless you can simplify those checks by changing the protection strategy making less critical the first shield integrity (reber boxes and polyethylene wrapping) by using, for example, the ultra pure nitrogen of the Borexino facility to flow the closets.

Another issue is space availability. The cuore-0 assembly tools take a lot of space (see Figure 12) but it is also true that only a small fraction of the cuore components will be ready and stored at the time of assembly.

Last but not least is the problem of time. If we ask the Borexino clean room to store our pieces it should be made clear that we will free the area only on cuore assembly completion that could be some years starting from now, if everything goes fine, more (and we cannot predict how much) if for any reason the production have some delay.

8.2. QC on storage tools and stored object

Since storage time could last years the main risk of recontamination comes from failures of the primary shielding (wrapping and vacuum boxes) and/or failures of the fluxing system of the storage closets.

In most of the cases and whenever it is possible we use Reber box to keep pieces under vacuum. These boxes are commercial stuff and their performances are not guaranteed of long periods of time. Nevertheless their transparency give us the chance to have a simple method to check the vacuum level inside the box by putting a vacuum probe inside the box which status can be checked by eye without opening the box or without using any other instrument.

A simple and cheap battery operated device could be done with the negative pressure sensor XFPM by Fujikura (the data sheet is at the end of the document) coupled with an ultra low power comparator (or any similar circuit). Two flashing LED (to minimize power consumption) monitor the status of the system. One, green, always on, guarantee the operator that the device is powered and working, the other, red, will start flashing if the negative pressure rise above a fixed threshold indicating that the vacuum is lost.

The dimensions of this device are those of an AA cell. The power consumption should be less of the order of the μA to guarantee more then one year lifetime without replace the battery.

This check should be done quite frequently if the failure of a box expose the components to a low purity atmosphere (for example evaporated nitrogen) or less frequently if closets are filled with high purity gas.

Closets integrity must be checked too (for safety reason) as well as the nitrogen flux.

Since this daily control could be very hard to maintain over long periods it is under study a remote surveillance system .

8.3. Services

- Evaporated Nitrogen line (P.S.A. in Cuoricino) or ultra pure nitrogen (P.S.A. in Borexino)
- Network and tools (PC, barcode readers ...) to manage the production database
- Cuoricino only: lift to carry the shipping boxes from the ground floor to the PSA

- packaging maintenance kits (vacuum pump, spare polyethylene bags and reber boxes
- Work table
- closets (the actual storage space)
- Borexino only: O2 sensor to be sure operators do not die for asphyxiation because of some leakage of the closets.

8.4. Closets

General requirements for the closet (not exhaustive list) are:

- must have transparent door to allow easy inspection of their content
- must be air tight
- must have in and exhaust N line connectors
- must have a pressure control system (bubbler or alike)
- the volume and space organization of each closet (hence the number and kind of pieces stored in) must be optimized taking into account
  - time needed to restore the N atmosphere after an opening (the less is better)
  - planned pieces throughput (driven by shipping and assembly procedures)

Good candidates may be the commercial desiccators proposed by R. Kadel at the June 2007 General Meting. See:
http://crio.mib.infn.it/wigmi/media/cuore/meetings/070619/21thJune/Kadel-CleanRoomAndParts.ppt and
http://www.terrauniversal.com/products/desiccators/nitroplexover.php

9. The assembly chain

9.1. Overview of the assembly chain

Currently the assembly chain has been divided in 6 (+1 for CUORE0) actions or steps:

- thermistor and heaters gluing on crystals
- pre-cabling of cable rails
- mechanical assembly of the tower
- installation of cable rods
- Bonding of thermistors and heaters
- Assembly of the copper shield (CUORE0 only)
- Final packing and transport in hall A (or wherever it should go)

All these actions will be performed inside seven different glove boxes. Each one designed ad-hoc (form factor, tools, number and position of the access, etc..) to optimize the job and minimize the difficulty of each step.
All the assembly tools and procedures will be tested and optimized before the startup of the production. This job will be done with the help of two tower-mockup and using all the real components (shipping box, clean-room, storage space etc...) we plan to use during the real assembly game.

9.2. The tower Mock-up

The tower mockups will be two with different level of fidelity just to make it possible to proceed with the development of the assembly line while other relevant parts of the game (like test of cleaning procedures or the assessment of copper pieces production) are underway and have not yet frozen.

The first full “dirty” tower mockup is currently under construction starting from a design of the mechanical structure slightly different from the very final design of a CUORE tower but retaining all its relevant features. This tower mockup will be used to help the design, the test and the fine tuning of all the tools and instruments used to assemble CUORE (glove-box, motorized motion etc...) and to sketch the skeleton of the assembly protocol.

The dirty mockup will be used in workshops or in lab during the development and construction of the tools used for the assembly and will never enter inside a clean-room.

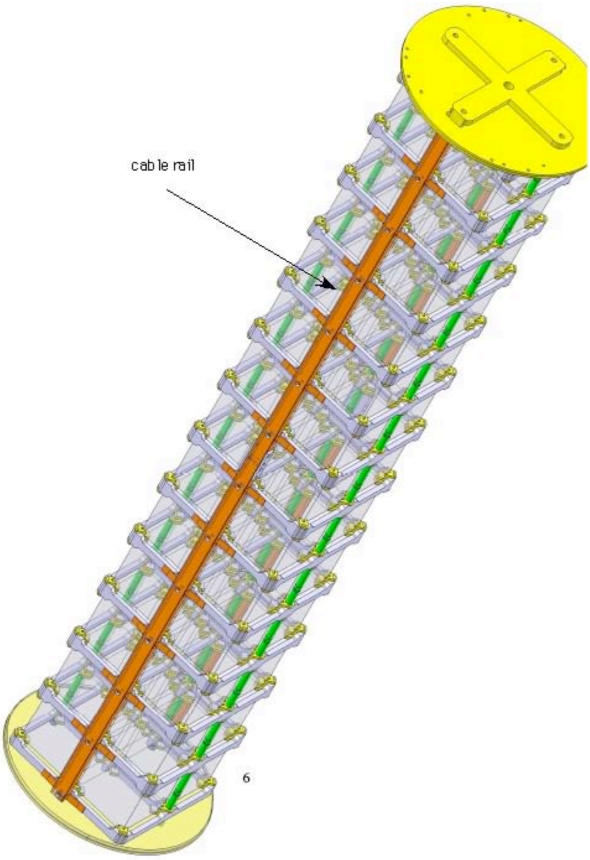
Once all the equipments will be ready they will be cleaned and installed inside the production clean room to start to simulate in real conditions the assembly procedure and finalize the final assembly protocol (that list of actions or sequence of actions that will be the operators' Bible)

During this phase a second tower mockup will be used. This last and final mockup must be an absolutely exact copy of a tower reproducing all its mechanical nuances. To make this true it means that the mock up must be the 20th CUORE tower coming from the same construction, cleaning, shipment chain as all the others.

With this object in hand the assembly protocol will be exhaustively tested, brought to perfection and finally released.

Gloves and other tools entered in touch with the mockup during training will be substituted o cleaned before starting the assembly of the real tower.

On the right a 3D sketch of the Cuore-0 naked tower (without shields). (Drawing courtesy of E. Tatananni LNGS)



9.3. Operators

The assembly procedure is divided into 7 actions. Some of them can proceed in parallel, others not. Although all of them are in principle reversible there are many cases where it could be very hard or dangerous to recover from mistakes or accidents. On the recontamination side things can only be worse.

Moreover CUORE assembly will last several months.

To be efficient and reduce the risk of error due to physicist ability to improvise and find innovative solution to trivial problems the job will be done by operators and not by member of the collaboration that will be, in any case, quite busy in supervising and manage the work. The quality of the work as well as how much time it will take will depends on our capability to propose smooth and easy procedures, to plan the job efficiently and on the care we put people training.

The numbers of people simultaneously at work in clean room is limited to 4

Assembly Glove Box Team:	max 3 operators (two working inside the glove box one serving the pieces) + a supervisor
Gluing Glove-Box Team:	max 3 operators (two working inside the glove box one serving the pieces) + a supervisor
Pre Cabling Team:	max 3 operators (two working inside the glove box one serving the pieces) + a supervisor
Tools Maintenance Team:	max 3 operators (two working inside the glove box one serving the pieces) + a supervisor
Storage area QC Team:	a couple of people

9.4. Operators training

A good training of operators it is considered one of the most relevant aspect of the whole project.

Operators training will start as soon as the assembly protocol have been released as stated in the previous chapter. They will play with the ”clean” mockup tower in clean room, acting exactly as they should doing the real job, up to the moment they will be able to assemble (and disassemble) a tower with their eyes closed while declaiming poems in Greeks....
This will be also our last opportunity to check, in the real world, the whole procedure. Feedback from the trainees could provide the latest hints to make the job the smoothest and simplest possible.
Only once operators will feel completely comfortable with the procedures the real assembly can start. No “learning while working” can be allowed..

9.5. *Preliminary operations*

9.5.1. *Gluing general remarks*

Gluing of chips will be done with different tools in Cuore-0 and Cuore but keeping identical all the features that have some impacts on the radio-purity of the process, the mechanical and bolometric performance of the crystals.
The only difference will be on the productivity side since the system developed for CUORE must face a much more aggressive and huge production schedule.
The quality of the glue spots (number of good spots, volumes of the drops, their height, diameter, pitch, air bubble inclusion, thickness after gluing etc...) are one of the most delicate aspects of bolometer assembly both with respect to its integrity after the cool down, and with respect to the bolometer response itself. Hence, regardless the actual gluing system adopted, it is quite important to have in both cases a QC tools capable to provide a complete picture of the gluing quality. This information can be used, immediately, to discard bad gluing (the criteria can be defined only once one of this system is operational and some test can be done), later, and this is one of the lessons we can learn from CUORE-0, to better understand the correlations among gluing quality and the bolometer response and its mechanical reliability.
In case of bad gluing the possibility to re-do the gluing on that crystal will depends on our capability to restore the initial cleanness of the crystal once all the operation needed to remove the glue and/or the chip have been done.
A procedure to accomplish this task must be deployed before any construction starts.

In both cases (CUORE-0 or CUORE) the gluing system will be operated inside an air tight glove box. This feature will make more difficult the task to keep track in the production database of the gluing quality indicators associated to a crystal. In some way the gluing procedure must preserve the possibility to identify crystals by their ID during and after gluing. The problem is that entering the gluing glove-box the polyethylene bags carrying the crystal ID labels are removed and the crystal loose any contact with it “identity card”.
The only way to maintain this information is to define a very precise procedure for handling the crystals inside the gluing glove box: during gluing operations, while aside waiting for glue polymerization, and when they are put back inside the ax-box.
The ax-box, like that used for shipment, will have again labels inside (on the naked Teflon holders?) and outside reporting the ID of the crystals.

9.5.1.1. *Gluing CUORE-0*

A manual method and tools to glue chips on crystals exist and have been used in all the assembly done for the hall C test.
A detailed description can be found elsewhere (missing ref.)

An evolution of this system, to be used for CUORE0, is under study in Como (see http://brain.dipscfm.uninsubria.it/deposito/incollino_draft.pdf or ask Marisa for more update documents)

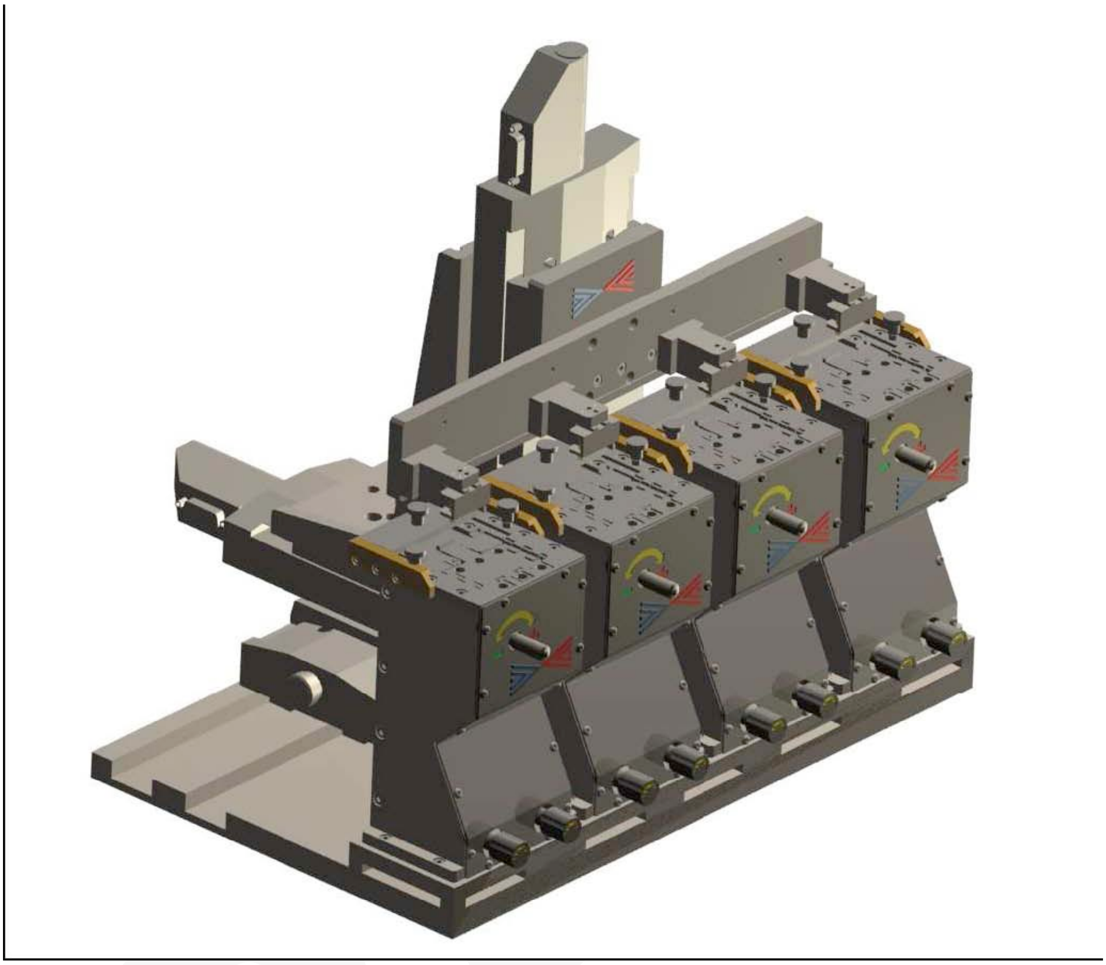


Figure 16: preliminary design of the gluing tool for CUORE0 under study at Como

The guidelines for the CUORE-0 project are:

- The coupling between thermistors (and heaters) and crystals will be done with Araldit
- Rapide glue;
- the glue will be deposited in the form of spots with diameter ~ 0.7 mm;
- the gap between the TeO_2 crystals and the chips will be 50 ± 5 microns;
- the gluing project should not depend on the chips dimensions;
- the gluing procedure has to be done in controlled atmosphere (glove box).
- the number of spots on thermistors are: XX
- the number of spots on heaters are: XX

A further requirement is:

- The glue spots will be deposited on the NTD thermistors and heaters .

9.5.1.2. Gluing CUORE

At LNGS is under study the system to be adopted to glue CUORE crystals. More details here as soon as they will be available.

As stated before the main features of the CUORE-O gluing process must be retained. Hence for CUORE too the guidelines of the project must be:

- The coupling between thermistors (and heaters) and crystals will be done with Araldit
- Rapide glue;
- the glue will be deposited in the form of spots with diameter ~ 0.7 mm;
- the gap between the TeO_2 crystals and the chips will be 50 ± 5 microns (or better);
- the gluing project should not depend on the chips dimensions;
- the gluing procedure has to be done in controlled atmosphere (glove box)

- the number of spots on thermistors are: XX
- the number of spots on heaters are: XX

A further requirement is:

- The glue spots will be deposited on the NTD thermistors and heaters.

9.5.2. pre-cabling

To cable Heathers and Thermistors Mylar strips with multiple printed copper tracks will be used. The number of tracks per strip have not been fixed yet hence the number and dimension of Mylar strips per tower have not been fixed too.

Strips lie inside a C-shaped copper cable rod to be fixed to the tower. A tower have two cable rod mounted on opposite sides with screws.

A complete cable rod is made by two cable rails (CRS top and bottom), two covers (CRC) + one joint (CRJ).

Cable rail are shipped on teflon holders needed to preserve the bending of the wings during shipment ,cable strip placement, and assembly.

The full package containing all the pieces needed to mount a cable rod enter the cabling glove box.

Cable rail holders are shorter then the rail segment leaving an access to the holes on the joint side of each piece. The sequence of assembly operations go as follow:

- Without removing the holders the two rails are aligned and coupled with the joint (a screw driver is needed to do this operation)
- The nylon screws that fix the rails on the holders are removed.
- The cable strips, that come already packed to fit the wings, are put in place and the pad location adjusted to fit precisely the wings.
- The strips are fixed by putting back the nylon screws
- The pad are glued on the wings (glue and gluing methods to be decided)
- **Step missing: the cable rod must be prepared to be mounted on the tower i.e. decoupled from the teflon holder. The nylon screws must be removed but a method to keep in place and do not mechanically stress the strips must be found**.
- The cable rod exit the cabling glove box and is stored somewhere in the clean room

9.6. The assembly glove boxes

While crystals, after the chip gluing stage, and cable trail, after their assembly stage, can be easily protected from recontamination with a simple packaging, the same is not true for the whole tower than must pass through several glove box before to be fully assembled.

To overcame this problem we propose a multi glove-boxes system + a "garage system" to safely house the tower during assembly.

Think about the system as of many space shuttles (the glove box trails) that docks to a space station (the glove box garage).

Both are air tight and with a controlled atmosphere inside.

The garage is equipped with a docking system that match that of the shuttles. Once the two object are coupled and the atmosphere normalized, what is inside the station can enter the shuttle without any contact with the external space.

Going back to the earth...

The garage (or tower station) is an air tight box, with a docking system on top

Inside the garage a mounting plate is placed on top of a lift (see figure 5)

With the lift in the bottom position, the tower is fully contained inside the garage. This is the "home" position.

The garage assure the respect of the zero-contact approach while the dedicated glove-box should make any of the single actions easy and, possibly, fast.

The role of the garage it's also to provide a safe place where the tower can rest if any problem which require a stop of the assembly chain, should occur.

The lift, as explained in the following, is used to move the tower in and out of the garage. The mounting plate can rotate by 360 deg. too.

The possibility to move the tower very precisely up and down and to rotate it is widely used to optimize the assembly actions.

The tower assembly chain starts with an empty garage, docked to the first glove-box (mechanical assembly), with the lift in the upper position and the mounting plate at the same level of the assembly table's plane.
Operators start assembly the first floor. Once the first floor have been completed the lift go down by one floor height putting the top of the floor done at the same level of the table's plane. The assembly of the second floor starts. The process go on like that until the whole tower have been done.

At the end of the process the lift is in the bottom position and the tower completely inside the garage. (A short animation of the sequence is available here:
http://www.roma1.infn.it/exp/cuore/room129/coredepapa/overview%20assembly.html)

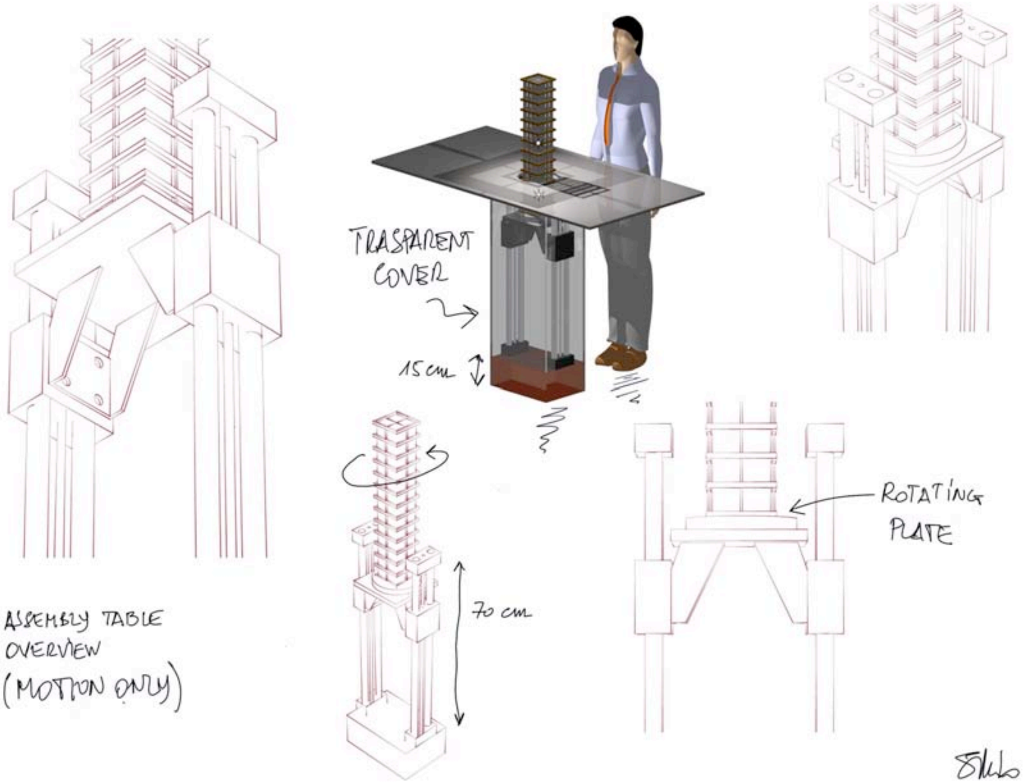


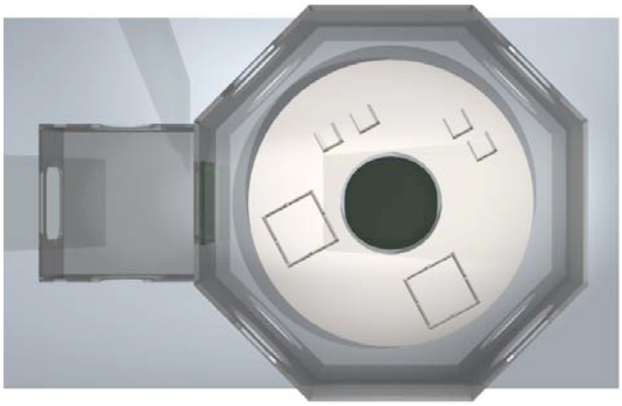
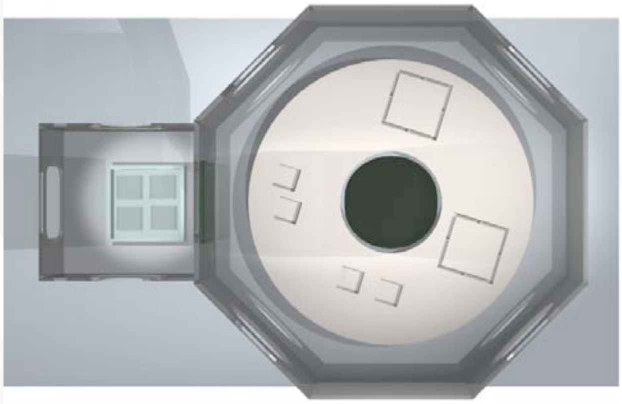
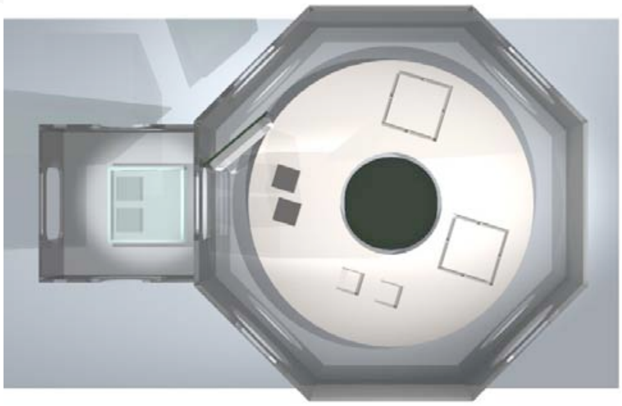
Figure 17: the lift inside the garage

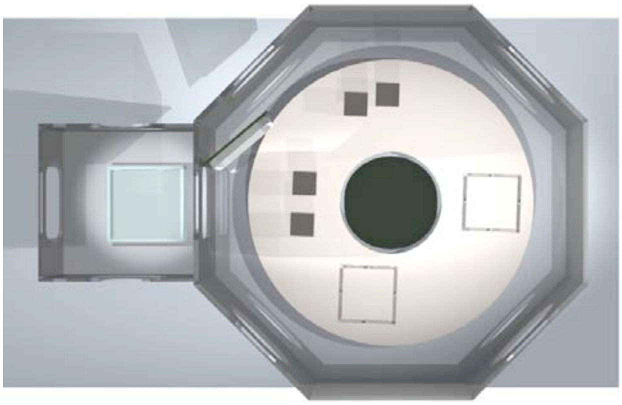
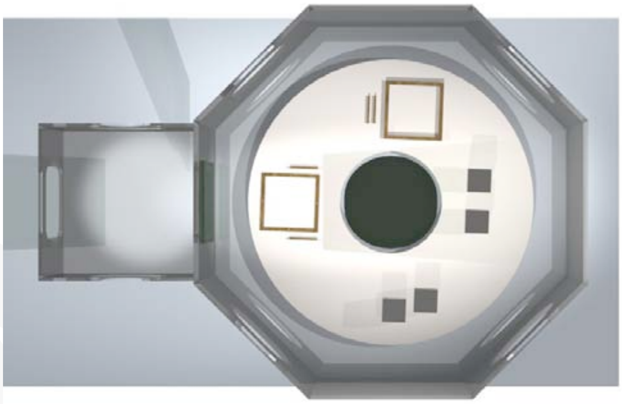
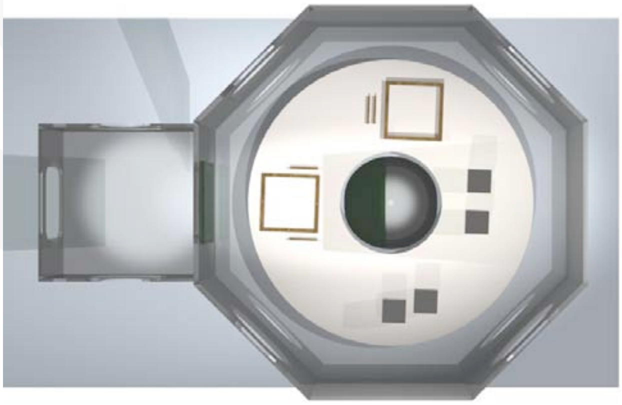
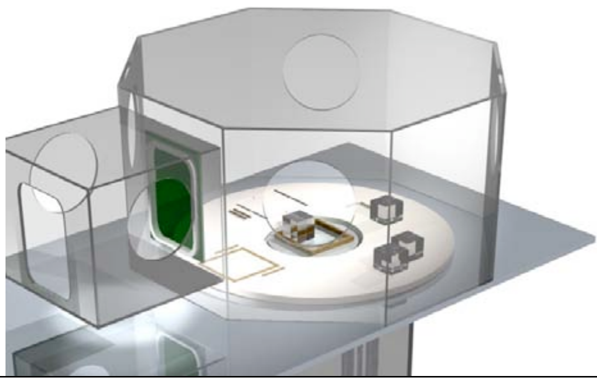
After closing the top of the garage the mech shuttle is moved apart and the garage is docked to the cabling-glove-box shuttle. Once the atmosphere of both volumes are normalized the tower enter the glove box rising the lift.
This sequence (assembly operation, tower down in the garage, shuttle exchange) is repeated up to the final step, where the tower, ready to be installed, enter the box designed for shipment and storage.
Glove box will be designed around the specific task that must be done inside.
To avoid any chance of contact of non radio-pure material with the towers and the tools used to work inside the box, the glove box will be equipped with "real" glove-box-gloves to fulfill the principle that it must be physically impossible to touch anything inside the box with something that is not already inside.

At the end of a cycle of operation the glove box could have some maintenance like the substitution of the gloves etc...

9.6.1. the mech. glove box

Here is a sample of how it could works the mechanical assembly of the tower inside the mech. glove box

The glove-box is empty. Both dock doors are closed, The lift is in the bottom position. The volume of the garage is flushed with nitrogen. The volume inside the glove box is flushed with nitrogen too.	
The door between the antechamber and the glove box is closed. The antechamber out door is open. The crystals' shipping box with the first 4 crystals enter the antechamber.	
The out door of the antechamber is closed. The air in the antechamber is pumped out and then the volume is fluxed with nitrogen. Once the antechamber is safe the operator open the crystals shipping box. One of the "assembly operators " (two) move the turning table to presents the crystals holders at the exit of the antechamber. Two crystals enter the mech. glove box	

The operation is repeated for the last two crystals. The exit door of the antechamber is closed. The antechamber is ready to enter the other pieces	
The same sequence is used to put inside the glove box all the other pieces needed to assemble one floor (frames, pillars, Teflon holders etc..)	
Once al the pieces are in, the garage door is opened and the lift risen to get the assembly plane at the same level of the table.	
The assembly of the plane can start	

A well trained operator should mechanically assembly a tower in less then one day.

(one working day is 8-hour divided in two turns)

9.6.2. cabling the tower

The cabling glove-box is used to fix the two pre-assembled cable trails to the tower.
Cable trails are mounted on opposite faces of the tower. Once the first cable trail is fixed the tower is rotated by 180 degree to allow the assembly of the second.

Number of simultaneous operator: 2 (one handling the piece inside the antechamber, the other working on the tower)

Its completely open the question on how to handle and pack the extra strips length (about 1 meter) exiting from the top of the cable trail

A well trained operator should mount the two cable rails on a tower in less then one day.

9.6.3. bonding the chip

The West Bond bonding machine have been modified by the firm to operate vertically. A test have been done in Como with a similar equipment to check the maximum deflection from the orthogonality between the bonding plane and the bonding tip that still ensure a successful bonding.
A well trained operator should be able to do the job with the bonding plane tilted up to +- 4 degree.
This fix the precision of the rotation system applied to the mounting plate.
The bonding machine will be completely enclosed into glove box volume.
Instead of the optical microscope normally found on such machine to point at the bonding area (few tenths of micron square), a CCD camera with a screen placed outside the box will be used.
The CCD camera must have an auto focus equipped multi-focal lens to provide the operator with the better view either during the long distance approach to the bonding zone or during the very last fine motion.

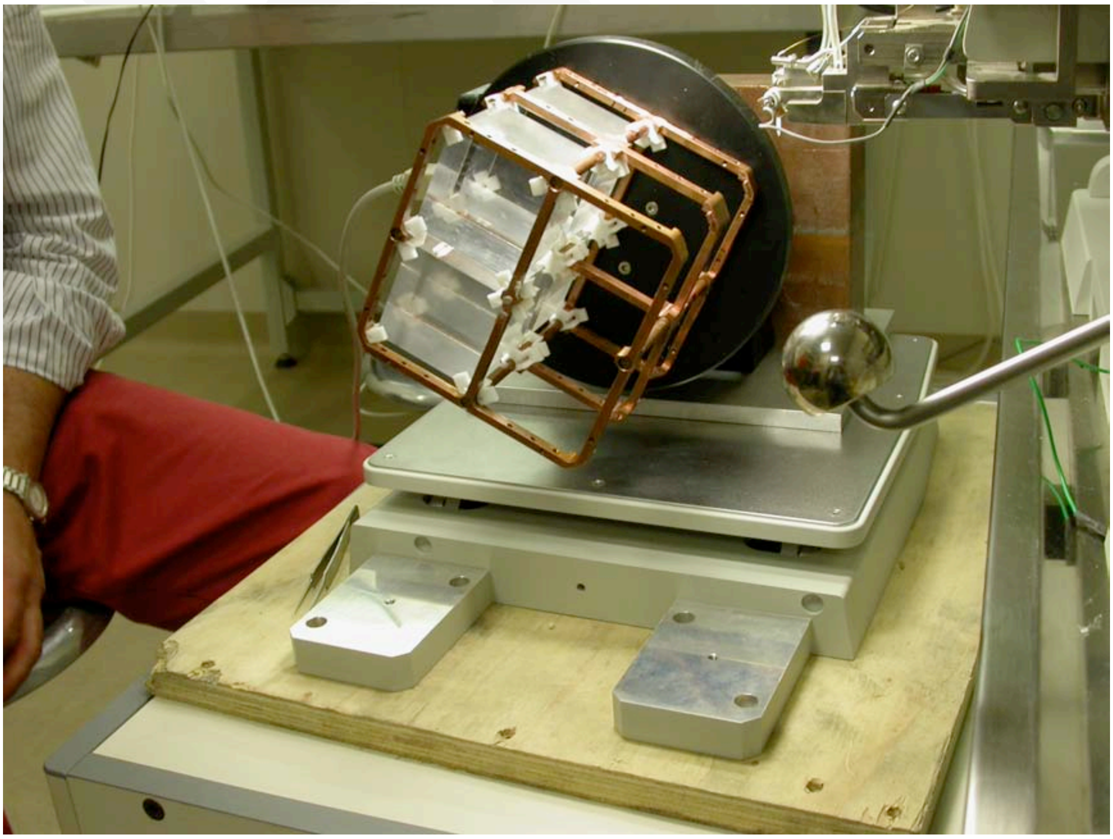


Figure 18: Bonding test in Como

The x-z position of the bonding machine will be fixed while it must move between two position in Y to have the bonding tip centered around the bonding zone of left or right crystals on one side of the tower.

The bonding procedures should go as follow:

- start position: BM centered on the left row. Tower raised up to one plane (the top plane) inside the glove box.
- bonding of heather and thermistor of the first crystal of the left row
- the lift rise by one plane
- bonding of heather and thermistor of the second crystal
- the lift rise by one plane
- ... loop
- bonding of the LAST crystal of the left row (on the bottom plane)
- Move BM to be centered on the right row
- bonding of the LAST crystal of the right row (on the bottom plane)
- the lift lowers by one plane
- bonding of the next crystal of the right row
- the lift lowers by one plane
- ..loop
- bonding of the first crystal of the right row (top plane)
- The tower enter the garage by lowering the lift by one plane
- The tower rotate by 180 degree
- the tower move up to present the first plane (top plane) to the BM
- ..loop as before

the procedure ends-up with the tower lowered and the cable exiting from top still inside the glove box.
Any search for broken or disconnected wire should be done at this stage.
The tower go home. The garage moves to the next station.

A conceptual design of this glove box can be done only once the bonding machine have been purchased and in our hands. At the time of writing the bonding machine is foreseen to be in Rome in May-June 2008

9.6.4. *the copper shield*

waiting for more input to design the copper shield-glove-box

9.6.5. *Final package & storage*

waiting for more input to design the stock-glove-box. In principle, for CUORE0 it will be the same as the copper shield glove box.

10. Appendix:

10.1. List of material and tools in direct contact with tower parts (to be completed)

(the purpose of this list is to be sure to have a recipe to properly clean all these objects)

what	Material choice	comments
Support plate on top of the garage lift	Aluminum, PVC, Teflon, copper..	It's the plane in contact with the Bottom Plate (cuore0) or the first frame (cuore) of the tower
Torque wrench (to tighten the copper pillar)	unknown	Only one kind found. An adapter must be done to fit the pillar size (5 mm)
Rotating plate inside the meck-box (to hold frame, pillars etc.. see par 4.4.4)	Teflon	
Glove-box gloves	Latex, Neoprene	Under rad-test at LNGS
Screwdriver(s)	unknown	
Frame-crystal spacers	Teflon	To fill the clearance between crystals and Teflon holders during bonding
Bonding machine tip		
Nitrogen	Nitrogen!. what else ?	Atmosphere inside the glove box
Tower Mock-up to be used to tune and test the assembly tools.	Standard Copper, Teflon	It will be in contact with all the above mentioned objects and/or tools. A second mock-up with "clean-copper" will be done and used during the training in clean room

10.3. List of materials and tools entering the clean room and facing (but not in touch with) the detectors elements (to be completed)

what	Material choice	Comments
Garage and glove-box walls	Perspex, steel	
Glove Box gasket (doors, glove holes etc..)	O-ring… rubber ?	
Small metallic components inside the glove-box (hinges, gas inlet/outlet etc..)	steel, copper, brass	
Working plane (assembling station tables)	steel, Aluminum	
Garage lift guide bearing	steel, Al	These pieces faces the tower when it is in home position
Step motor, hose fitting & other mechanical components of the lift motion system	steel	Will be housed in a closed box at the bottom of the garage.
Bonding Machine (including electronics)	..	It goes inside the bonding glove box ad it will face the tower.
CCD and LCD screen	Most plastic	Bonding pointing system.

10.4. *List of tools and parts that goes inside the clean room (to be completed)*

(the purpose of this list is to be sure to have a recipe to properly clean all these objects)

what	material	comments
Garage rails	Al, Inox	
chairs		
Nitrogen in/exhaust pipes	Teflon, PVC	
Vacuum pipes		
Vacuum pump		Aspirazione aria dalle glove box
Cable (power and signal)		
Frames storage/transport box		
Pillar storage/transport box		
Screw storage/transport box		
Top/Bottom Plates storage/transport box		
Cable rail storage/transport box		
Strip storage/transport box		
Shields storage/transport box		
Hood (for chemical)		
Ultrasonic bath		
Table (general purpose)		
Storage box		

10.5. Summary of the CUORE-0 assembly sequence

a) GLUING STATION
   a. gluing of heathers and thermistors

b) CABLE RAIL ASSEMBLY STATION
   a. mechanical assembly of the cable rail plus cover
   b. strips placement inside the cable rail
   c. pads gluing on the cable rail "wings"

c) ASSEMBLY STATION 1: (TOWER MECHANICAL ASSEMBLY)
   00. dock garage and shuttle1
   01. flush nitrogen in shuttle1
   02. open garage dock door
   03. put garage lift in TOP position (see picture)
      a. BOTTOM plane' parts enter the glove box
      b. place bottom plate on assembly plane
      c. place first frame
      d. place bottom teflon holders
      e. screw pillars
      f. put crystals in place
      g. fix crystals with teflon spacers
   04. lift down by one plane
      a. pieces for the GENERIC plane enter the glove box
      b. place top teflon holders
      c. place frame
      d. place bottom teflon holders
      e. screw pillars
      f. place crystals
      g. fix crystals with teflon spacers
   05. lift down by one plane
      a. ...

   06. lift down by LAST plane
      a. pieces for the TOP plane enter the glove box
      b. place top teflon holders
      c. place top frame
      d. temporary fix top frame with screws

   07. lift at home, the tower is inside the shuttle
   08. close garage door
   09. dock garage and shuttle2
   10. flush nitrogen in shuttle2
   11. open garage dock door
   12. put garage lift in TOP position
   13. The tower is inside Shuttle2

d) ASSEMBLY STATION 2: (shield/CABLING GLOVEBOX)
   a. rotate the tower (if needed) in the right position
   b. First cable rail enter the glove box
   c. Fix the first cable rail to the tower
   d. Fix the floating cable on top of the tower
   e. Rotate the tower by 180 (or whatever) degrees
   f. Second cable rail enter the glove box
   g. Fix the second cable rail
   h. Fix the floating cable on top of the tower
   i. The first cover enter the glove box
   j. place the cover on the cable rail
   k. Rotate the tower by 180 degrees
   l. The last cover enter the glove box

m. Place the cover on the second cable rail

01. lift at home, the tower is inside the shuttle
02. close garage door
03. dock garage and shuttle3
04. flush nitrogen in shuttle3
05. open garage dock door
06. put garage lift in TOP position
07. The tower is inside Shuttle3

e) Bonding Glove-Box (work in progress...)
   00. la torre sale un piano alla volta
   01. bonding pad heaters e termistori dx
   02. end: torre copletamente alzata
   03. translate bonding machine position
   04. la torre scende un piano alla volta
   05. bonding pad heaetrs termistori sx
   06. Repeat if more then 1 cable rail
   07. Tower inside the garage

f) shield/cabling Glove-Box (work in progress...)
   00. tower rising (un piano alla volta)
   01. rimozione tasselli ancoraggio cristalli
   02. tower reach top
   03. tower coming down
   04. posizionamento schermi (dal basso)
   05. tower full down
   06. rimozione viti provvisorie top frame
   07. inserimento top plate e passaggio strip
   08. fissaggio top plate (viti)
   09. la torre scende in garage

g) shipping box (work in progress...)
   00. rise tower
   01. connect top plate with shipping box top
   02. pick up shipping box
   03. close bottom of the shipping box

(*) le colonnine del primo piano fissano il frame al bottom plate ? if not perche no ?
(**) trovare un modo per tenere insieme il mastriccio di strip in modo compatto. Extra spazio da calcolare sia per garage che per le glove box full size.

10.7. Summary of CUORE assembly sequence

10.8. Summary of parts for Shipping (protective enclosure for shipping)

Part Name	Qnty	Spare	Total	
Crystals	18	2	20	commercial
Frames	54	6	60	commercial
Pillars	65	5	70	commercial
Cable rail	31	2	33	commercial
Screw	28	2	30	commercial

Only protective box used for shipment of clean parts from SICCAS or LNL are considered
Qnty equal the number of individual shipments

10.9. Summary of parts for Storage (Boxes that go inside the PSA + accessories)

Part Name	Qnty	Spare	Total		
X-BOX (PSA)	122	6	128	commercial	
AX-BOX (PSA)	80	4	84	commercial	
Naked Holder	80	4	84	custom made	
Wrapped Holder	4	2	6	custom made	
IKEA shell 3 cm (PSA)	48	4	52	commercial	
IKEA shell 7 cm (PSA)	276	12	288	commercial	
Teflon plate	324	16	340	custom made	
P-Box (PSA)	65	2	67	commercial	
CR-Box (PSA)	31	1	32	custom made	?
H-Box (PSA)	28	1	29	commercial	
ST-Box (PSA)	48	2	50	custom made	
cable rail holder	14	2	16	custom made	
bobby pins	14	2	16	custom made	
nylon screws	28	12	40	commercial	
Teflon Holders	--	--	--	commercial	

Qnty: include the boxes for spare parts
Spare: is the number of spares boxes (or components of the shipping package)

11. Project Check List

	TTA	SM	0	0 - 10	10-50	50-80	80-100
Crystals:							
Production site	2008						
Production contract							
delivery rate		•					
shipping packaging	2008	•					
Copper:							
Production site	2008						
Production contract							
delivery rate		•					
shipping packaging	2008	•					
Teflon:							
Production site	2008						
Production contract							
delivery rate		•					
shipping packaging	2008	•					
Cable:							
Production site	2008						
Production contract							
delivery rate		•					
shipping packaging	2008	•					
Chip:							
Production site	2008						
Production contract							
delivery rate		•					
shipping packaging	2008	•					
Assembly tools status:							
Gluing machine	2008						
Gluing Glove Box	2008	•					
Mech glove box	2008	•					
Cabling glove box	2008	•					
Bonding glove box	2008	•					
Storage glove-box	2008	•					
Mockup 1	2008	•					
Mockup 2	2008	•					
Storage Area (space and infrastructure):							
As shipped	2008	•					
Re-packed		•					
Towers		•					
Nitrogen Facility	2008	•					
Nitrogen distribution	2008	•					
Storage Tools (package that fit space and infrastructure):							
crystals	2008	•					
copper	2008	•					
teflon	2008	•					
cable	2008	•					
chip	2008	•					
Assembly spaces and infrastructure:							
Borexino clean room	2008	•					
Re-pack clean area	2008	•					
Cuore clean room		•					

Protocols:							
As shipped acceptance	2008	•					
As shipped storage QC	2008	•					
Re-packed storage QC	2008	•					
Towers storage QC		•					
Gluing operation	2008						
Pre-Cabling operation	2008	•					
Mechanical assembly	2008	•					
Cabling operation	2008	•					
Bonding operation	2008	•					
Tower Storage QC		•					

12. Data Sheet

12.1. Contenitore IKEA x Frames

IKEA 365+

Contenitore per alimenti

misure

17x17x3 cm

Il prezzo si riferisce alle opzioni selezionate sopra

€ 1,99

ingrandisci l'immagine

Informazioni sul prodotto

Caratteristiche principali

- La valvola sul coperchio e gli angoli arrotondati garantiscono un riscaldamento efficace e uniforme nel microonde.
- Ideale per scongelare e riscaldare i cibi nel microonde.
- Il coperchio ermetico evita che gli alimenti si danneggino durante il congelamento e previene le perdite.
- Impilabile: permette di guadagnare spazio nel frigo e nel congelatore.

designer:

Håkan Olsson

Misure del prodotto

Lunghezza: 17 cm
Larghezza: 17 cm
Altezza: 3 cm
Capacità: 0.3 l

manutenzione

Si può mettere nel forno a microonde, max. 120°C.
Si può mettere nel congelatore.
Si può mettere in lavastoviglie, nel cestello superiore.

descrizione e misure del prodotto

Plastica propilenica, Gomma sintetica

misure e peso della confezione
(1 totale confezioni)

12.2. Ikea Shell Usage

12.3. Reber VuotoBox

Contenitori per sottovuoto in policarbonato	
6703 A Contenitore rotondo da Litri 2 *con coperchio diametro cm.22*	
6702 A Contenitore rotondo da Litri 4 *con coperchio diametro cm.22*	
6750 A Contenitore rettangolare 20x25 *con coperchio per sottovuoto e coperchio salvafreschezza*	
6751 A Contenitore rettangolare 20x25 a 2 scomparti *con coperchio per sottovuoto e coperchio salvafreschezza*	
6752 A Contenitore rettangolare 20x25 a 3 scomparti *con coperchio per sottovuoto e coperchio salvafreschezza*	
6756 A Contenitore rettangolare 20x13 *con coperchio per sottovuoto e coperchio salvafreschezza*	
Contenitori in moplen	
6753 A Contenitore rettangolare 20x25 (non per sottovuoto) *con coperchio salvafreschezza*	
6754 A Contenitore rettangoare 20x25 a 2 scomparti *con coperchio salvafreschezza*	
6755 A Contenitore rettangolare 20x25 a 3 scomparti *con coperchio salvafreschezza*	
6757 A Contenitore rettangolare 20x13 *con coperchio salvafreschezza*	

Box in polycarbonate, O-ring in Teflon

Coperchi universali per sottovuoto in policarbonato	
6712 A Coperchio Universale Ø 4 - 9 cm.	
6711 A Coperchio Universale Ø 4 - 12 cm.	
6709 A Coperchio Universale Ø 12 - 16 cm.	
6708 A Coperchio Universale Ø 16 - 20 cm.	
6710 A Coperchio per Pentole e Contenitori Ø 22 cm.	
6716 A Coperchio Universale Rettangolare 16 - 20 cm.	
6718 A Coperchio Rettangolare 20x25 cm.	
6720 A Coperchio Rettangolare 20x13 cm.	
Attacchi per contenitori	
6727 A Attacco Piccolo per Contenitori Reber	
6707 A Attacco Grande per Vasi in Vetro (per Family, De Luxe e Professionali)	
6704 A Attacco Grande per Vasi in Vetro con sfiato aria (per Junior e Salvaspesa)	

Box in polycarbonate, O-ring in Teflon.
Vacuum: -900 mBar

12.4. Reber Buste

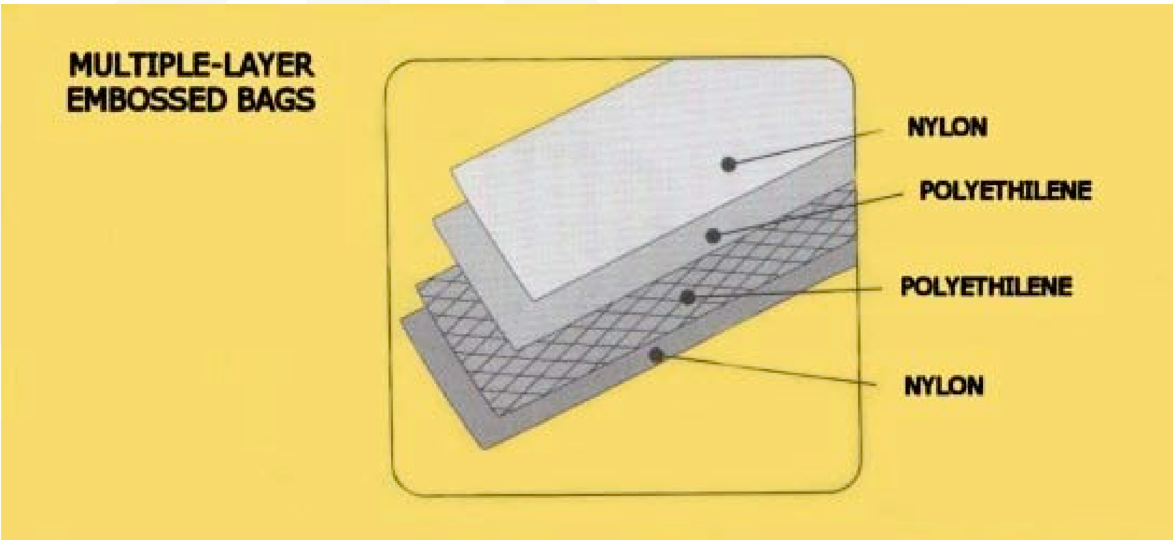
Sacchetti multistrato goffrati o con impronta specifici per sottovuoto - spessore 105

Confezionati in buste sigillate, con codice a barre

6745 A	Busta 100 Sacchetti 15x25	6723 A	Busta 100 Sacchetti 20x30
6735 A	Busta 100 Sacchetti 30x40	6728 A	Busta 100 Sacchetti 15x40
6722 A	Busta 20 Sacchetti 20x30	6748 A	Busta 20 Sacchetti 22x65
6749 A	Busta 20 Sacchetti 30x80		
6726 A	Busta 2 rotoli cm. 20 x 6 metri	6725 A	Busta 2 rotoli cm. 30 x 6 metri

Misure disponibili: cm. 15x25, 20x30, 30x40, 15x40; 22x65, 30x80;
Rotoli da 20 cm. e 30 cm. di larghezza per 6 metri.

REBER vacuum devices use special embossed multiple-layer bags, which are specific for vacuum packaging. Exterior side is of nylon, to guarantee the best airproof; interior side is of polyethylene, which is ideal for foodstuffs packaging. Bags are made of four layers, three are smooth and one is embossed, to achieve the maximum air suction. Bags thickness of 105 micron guarantees its robustness, avoiding accidental breaking.



12.5. ORVED Buste Goffrate

SACCHETTI SOTTOVUOTO GOFFRATI - PA/PE 20/80 - 100 μm:
ideali per il confezionamento con MACCHINE AD ESTRAZIONE ESTERNA PROFESSIONALI e PER USO DOMESTICO; si possono utilizzare anche con MACCHINE A CAMPANA.
PER CONSERVAZIONE E COTTURA A MAX +70°C

CHANNELLED VACUUM BAGS - PA/PE 20/80 - 100 μm:
ideal for vacuum packing with HOUSEHOLD AND PROFESSIONAL EXTERNAL SUCTION MACHINES; it is also possible to use them with CHAMBER VACUUM PACKING MACHINES.
FOR CONSERVATION AND COOKING MAXIMUM TEMPERATURE +70°C

TIPO DI ANALISI/PROPERTIES	VALORE/VALUE	UNITA' DI MISURA/UNIT	METODO/METHOD
Spessore totale/Total thickness	100	micron	DIN 53370
Permeabilità al vapore acqueo - Misurata a 23° C con 85% u.r. Water Vapor Transmission rate - Measured at 23°C and 85% R.H.	2,3	gr/mq - 24 h	DIN 53122
Permeabilità all'ossigeno - Misurata a 23° C con 0 % u.r. Oxygen Permeability - Measured at 23°C and 0% R.H.	50	cm^3/mq - 24 h - bar	DIN 53380
Resistenza alla lacerazione longitudinale Tensile strength at Break Long. D.	>45	N/15 mm	DIN EN ISO 527-1
Resistenza alla lacerazione trasversale Tensile strength at Break Cross. D.	>35	N/15 mm	DIN EN ISO 527-3
Allungamento fino alla rottura longitudinale Elongation at Break Long. D.	>200	%	DIN EN ISO 527-1
Allungamento fino alla rottura trasversale Elongation at Break Cross. D.	>250	%	DIN EN ISO 527-3
Peso per area/Weight per area	96,4	g/m^2	DIN ISO 536
Resistenza della saldatura - 150°C/5bar/1,0 sec. Seal strength - 150°C/5bar/1,0 sec.	>30	N/15 mm	

I valori indicati qui sopra descrivono proprietà tipiche, ma non costituiscono limitazioni specifiche
The values indicated above describe typical properties, but do not constitute specification limits

12.6. ORVED VuotoBox

VUOTO BOX

DIMENSIONI VUOTO BOX ROTONDI

DIAMETRO: 190 mm	ALTEZZA: 100 mm
DIAMETRO: 230 mm	ALTEZZA: 125 mm
DIAMETRO: 270 mm	ALTEZZA: 135 mm

DIMENSIONI VUOTO BOX RETTANGOLARI

DIMENSIONI:	200 x 142 x 75h mm
	250 x 175 x 95h mm
	230 x 340 x 115h mm

COPERCHI SINGOLI DISPONIBILI ROTONDI

DIAMETRO:	70 mm
	90 mm
	100 mm
	50 - 90 mm
	85 - 150 mm
	90 - 260 mm

COPERCHI SINGOLI DISPONIBILI RETTANGOLARI

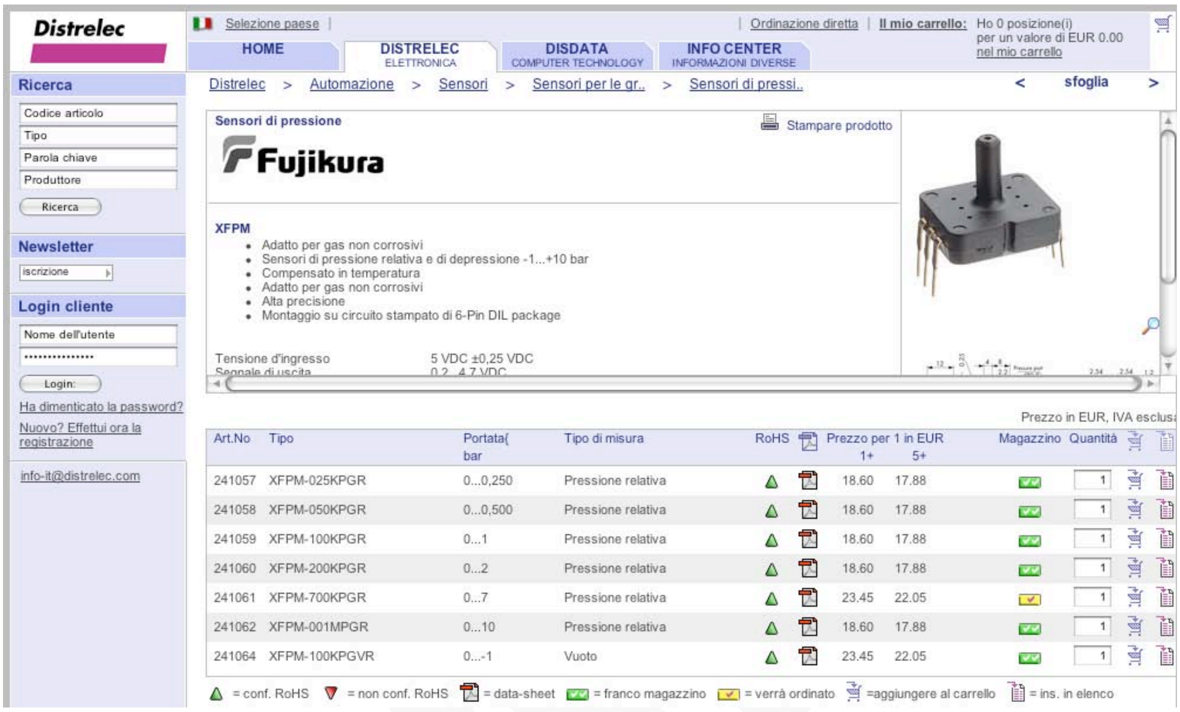
DIMENSIONI:	150 x 230 mm
	210 x 310 mm

CONFEZIONI TAPPI DA BOTTIGLIA

QUANTITA':	2 tappi per confezione

ORVED srl unipersonale
Via dell'Artigianato, 30 - 30024 Musile di Piave (VE) - tel: ++39.0421.54387 - fax: ++39.0421.332295
Export Office: tel: ++39.045.576259 - fax: ++39.045.8100124
R.E.A.: VE 235301 - Cod.Fisc. e P.I.V.A. : IT02708910274
www.orved.it - email: orved@orved.it

12.7. Pressure Sensors



Pre-amplified/5V Excitation/Gauge — XFPM,XFHM Data sheet

■Features

· Two accuracy ranks, ±1.5%FS and ±2.5%FS available
· Volt level output
· On-chip amplification and temperature compensations
· Pre-calibration of offset voltage and span
· Non-corrosive liquid measurable (XFPMC, XFHMC only)

■Applications

· Industrial instrumentation
· Pressure switch, Pneumatic device
· Medical device

■Part number for ordering

XFPM C - 025KP G R H

Model
XFPM
XFHM

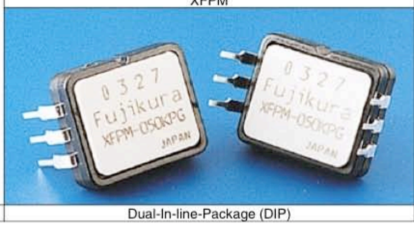
Available pressure media
No mark : Non-corrosive gas only
C : Non-corrosive gas and liquid

Rated pressure (Pa)

Pressure type
G : Gauge (Positive pressure)
GV : Gauge (Negative pressure)
GW : Gauge (Bipolar pressure)

Terminal leads direction
(See Outline Diagram)
No mark :
R :

Accuracy
No mark : ±2.5%FS
H : ±1.5%FS

Pressure type	Gauge pressure	
	XFPM	XFHM
Model		
Package configuration	Dual-In-line-Package (DIP)	Horizontal pressure port DIP

Measurable pressure range (kPa)	Part number for ordering							
−100～100	XFPM-100KPGW(H)	XFPM-100KPGWR(H)	XFPMC-100KPGW(H)	XFPMC-100KPGWR(H)	XFHM-100KPGW(H)	XFHM-100KPGWR(H)	XFHMC-100KPGW(H)	XFHMC-100KPGWR(H)
0～−100	XFPM-100KPGV(H)	XFPM-100KPGVR(H)	XFPMC-100KPGV(H)	XFPMC-100KPGVR(H)	XFHM-100KPGV(H)	XFHM-100KPGVR(H)	XFHMC-100KPGV(H)	XFHMC-100KPGVR(H)
0～25	XFPM-025KPG(H)	XFPM-025KPGR(H)	XFPMC-025KPG(H)	XFPMC-025KPGR(H)	XFHM-025KPG(H)	XFHM-025KPGR(H)	XFHMC-025KPG(H)	XFHMC-025KPGR(H)
0～50	XFPM-050KPG(H)	XFPM-050KPGR(H)	XFPMC-050KPG(H)	XFPMC-050KPGR(H)	XFHM-050KPG(H)	XFHM-050KPGR(H)	XFHMC-050KPG(H)	XFHMC-050KPGR(H)
0～100	XFPM-100KPG(H)	XFPM-100KPGR(H)	XFPMC-100KPG(H)	XFPMC-100KPGR(H)	XFHM-100KPG(H)	XFHM-100KPGR(H)	XFHMC-100KPG(H)	XFHMC-100KPGR(H)
0～200	XFPM-200KPG(H)	XFPM-200KPGR(H)	XFPMC-200KPG(H)	XFPMC-200KPGR(H)	XFHM-200KPG(H)	XFHM-200KPGR(H)	XFHMC-200KPG(H)	XFHMC-200KPGR(H)
0～1000	XFPM-001MPG(H)	XFPM-001MPGR(H)	XFPMC-001MPG(H)	XFPMC-001MPGR(H)	XFHM-001MPG(H)	XFHM-001MPGR(H)	XFHMC-001MPG(H)	XFHMC-001MPGR(H)

■Specifications

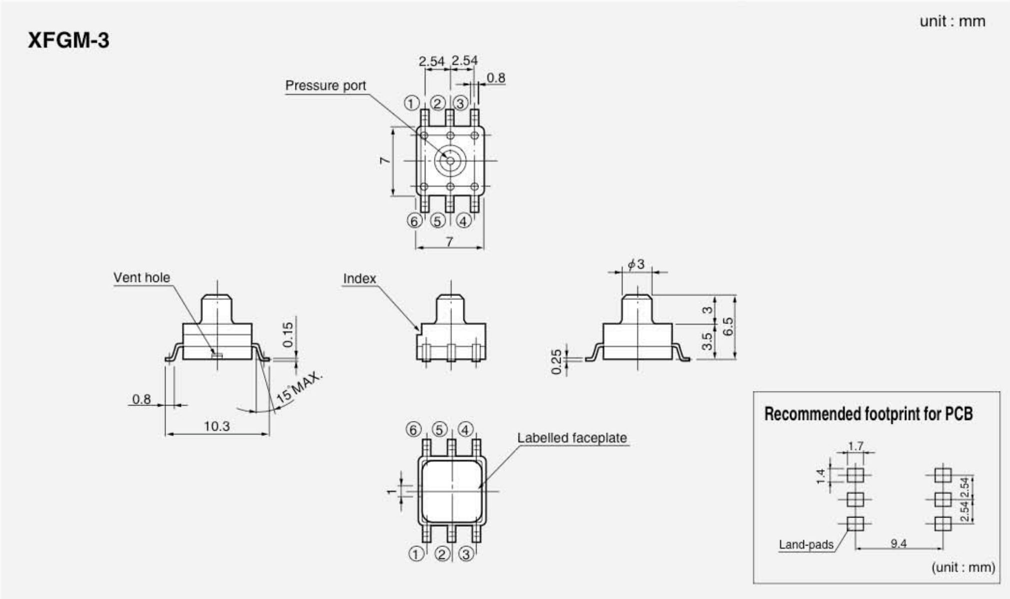
Model/Rated pressure	100KPGW(H)	100KPGV(H)	025KPG(H)	050KPG(H)	100KPG(H)	200KPG(H)	001MPG(H)	Unit
Recommended operating conditions								
Pressure type	Gauge pressure							—
Rated pressure	±100	−100	25	50	100	200	1000	kPa
	±1.020	−1.020	0.255	0.510	1.020	2.040	10.20	kg/cm²
Measurable pressure range	−100～100	0～−100	0～25	0～50	0～100	0～200	0～1000	kPa
Pressure media ※1	XFPM, XFHM : Non-corrosive gas only, XFPMC, XFHMC : Non-corrosive gas and liquid							—
Excitation voltage	5.0±0.25							VDC
Absolute maximum rating								
Maximum load pressure	Twice of rated pressure						1.5times of rated pressure	—
Maximum excitation voltage	8							VDC
Operating temperature	−40～125							℃
Storage temperature	−40～125							℃
Operating humidity	30～80 (No dew condensation)							%RH
Electric performances/characteristics(Excitation voltage Vcc=5.0V constant, Ambient temperature Ta=25℃)								
Current consumption	less than 10							mA
Output impedance	less than 10							Ω
Source current	less than 0.2							mA
Sink current	less than 2							mA
Mechanical response time	2 (For the reference)							msec
Full scale span voltage	4.5							V
Offset voltage ※2	0.2±0.1125, 0.2±0.0675(H)							V
Full scale span voltage ※2	4.7±0.1125, 4.7±0.0675(H)							V
Accuracy ※2	2.5, ±1.5(H)							%FS/0～85℃

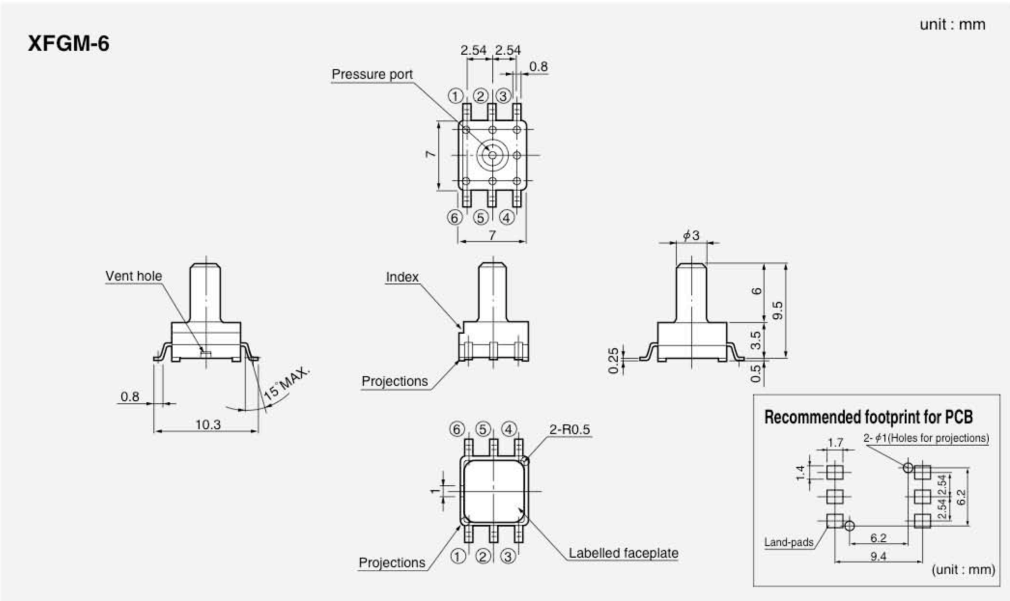
Note ; ※1) Please consult us available liquid pressure media when you choose the C models.
※2) Excluding input voltage error.

Fujikura

Pre-amplified/5V Excitation/Gauge | **XFGM-3,XFGM-6 Data sheet**

■ Outline dimensions ■

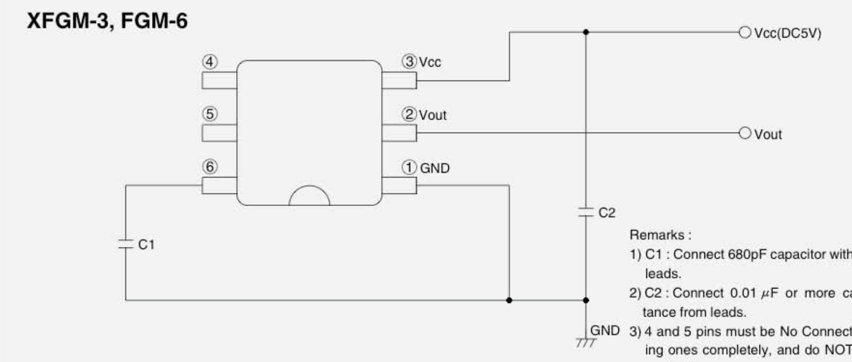




Fujikura

Pre-amplified/5V Excitation/Gauge | **XFGM-3,XFGM-6 Data sheet**

■ Connection diagram ■



Remarks :
1) C1 : Connect 680pF capacitor within 2cm distance from leads.
2) C2 : Connect 0.01 μF or more capacitor within 2cm distance from leads.
3) 4 and 5 pins must be No Connection. Open them as floating ones completely, and do NOT connect to other line or each other.

Note ; Please read instruction “Notes” before using the sensor.
Fujikura reserves the right to change specifications without notice.

Fujikura Ltd.
If you have any questions regarding technical issues or specifications, please contact us.
Sensor Engineering Department 5-1 Kiba 1-chome, Koto-ku, Tokyo 135-8512, Japan
Phone +81-(0)3-5606-1072 Fax. +81-(0)3-5606-1538
E-mail : sensor@fujikura.co.jp

12.8. Low Power comparator

(da abbinare a sensore di pressione. Catalogo DISTRELEC)

https://www.distrelec.it:443/ishopWebFront/catalog/product.do/para/language/is/it/and/shop/is/IT/and/id/is/01/and/node/is/acaaabacacad/and/series/is/1.html

19-0194; Rev 1; 2/97

MAXIM

Ultra Low-Power, Low-Cost Comparators with 2% Reference

MAX931-MAX934

General Description

The MAX931-MAX934 single, dual, and quad micropower, low-voltage comparators plus an on-board 2% accurate reference feature the lowest power consumption available. These comparators draw less than 4µA supply current over temperature (MAX931), and include an internal 1.182V ±2% voltage reference, programmable hysteresis, and TTL/CMOS outputs that sink and source current.

Ideal for 3V or 5V single-supply applications, the MAX931-MAX934 operate from a single +2.5V to +11V supply (or a ±1.25V to ±5V dual supply), and each comparator's input voltage range extends from the negative supply rail to within 1.3V of the positive supply.

The MAX931-MAX934's unique output stage continuously sources as much as 40mA. And by eliminating power-supply glitches that commonly occur when comparators change logic states, the MAX931-MAX934 minimize parasitic feedback, which makes them easier to use.

The single MAX931 and dual MAX932/MAX933 provide a unique and simple method for adding hysteresis without feedback and complicated equations, using the HYST pin and two resistors.

For applications that require increased precision with similar power requirements, see the MAX921-MAX924 data sheet. These devices include a 1% precision reference.

PART	INTERNAL 2% REFERENCE	COMPARATORS PER PACKAGE	INTERNAL HYSTERESIS	PACKAGE
MAX931	Yes	1	Yes	8-Pin DIP/SO/ µMAX
MAX932	Yes	2	Yes	8-Pin DIP/SO/ µMAX
MAX933	Yes	2	Yes	8-Pin DIP/SO/ µMAX
MAX934	Yes	4	No	16-Pin DIP/SO

Applications

Battery-Powered Systems
Threshold Detectors
Window Comparators
Oscillator Circuits
Alarm Circuits

Features

- Ultra-Low 4µA Max Quiescent Current Over Extended Temp. Range (MAX931)
- Power Supplies:
  Single +2.5V to +11V
  Dual ±1.25V to ±5.5V
- Input Voltage Range Includes Negative Supply
- Internal 1.182V ±2% Bandgap Reference
- Adjustable Hysteresis
- TTL-/CMOS-Compatible Outputs
- 12µs Propagation Delay (10mV Overdrive)
- No Switching Crowbar Current
- 40mA Continuous Source Current
- Available in Space-Saving µMAX Package

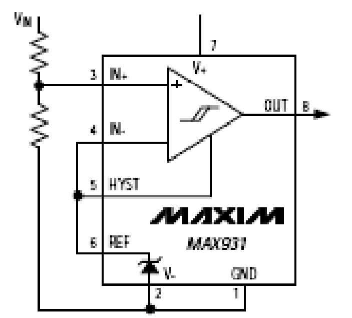
Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE
MAX931CPA	0°C to +70°C	8 Plastic DIP
MAX931CSA	0°C to +70°C	8 SO
MAX931CUA	0°C to +70°C	8 µMAX
MAX931EPA	-40°C to +85°C	8 Plastic DIP
MAX931ESA	-40°C to +85°C	8 SO

Ordering Information continued on last page.

For similar devices guaranteed over the military temp. range, see the MAX921-MAX924 data sheet. The MAX931, MAX933, and MAX934 are pin-compatible with the 1% accurate MAX921, MAX923, and MAX924, respectively. The MAX932 and MAX922 are not pin-compatible.

Typical Operating Circuit



THRESHOLD DETECTOR

12.8.1. Threshold LED driver circuit

Ultra Low-Power, Low-Cost Comparators with 2% Reference

100nA for the thresholds to be accurate. R1 values up to about 10MΩ can be used, but values in the 100kΩ to 1MΩ range are usually easier to deal with. In this example, choose R1 = 294kΩ.

3. Calculate R2 + R3. The overvoltage threshold should be 5.5V when V_{IN} is rising. The design equation is as follows:

$$R2 + R3 = R1 \times \left(\frac{V_{OTH}}{V_{REF} + V_H} - 1 \right)$$

$$= 294k \times \left(\frac{5.5}{(1.182 + 0.005)} - 1 \right)$$

$$= 1.068M\Omega$$

4. Calculate R2. The undervoltage threshold should be 4.5V when V_{IN} is falling. The design equation is as follows:

$$R2 = (R1 + R2 + R3) \times \frac{(V_{REF} - V_H)}{V_{UTH}} - R1$$

$$= (294k + 1.068M) \times \frac{(1.182 - 0.005)}{4.5} - 294k$$

$$= 62.2k\Omega$$

Choose R2 = 61.9kΩ (1% standard value).

5. Calculate R3.

$$R3 = (R2 + R3) - R2$$

$$= 1.068M - 61.9k$$

$$= 1.006M\Omega$$

Choose R3 = 1MΩ (1% standard value).

6. Verify the resistor values. The equations are as follows, evaluated for the above example.

Overvoltage threshold:

$$V_{OTH} = (V_{REF} + V_H) \times \frac{(R1 + R2 + R3)}{R1}$$

$$= 5.474V.$$

Undervoltage threshold:

$$V_{UTH} = (V_{REF} - V_H) \times \frac{(R1 + R2 + R3)}{(R1 + R2)}$$

$$= 4.484V,$$

where the hysteresis voltage $V_H = V_{REF} \times \frac{R5}{R4}$.

Bar-Graph Level Gauge

The high output source capability of the MAX931 series is useful for driving LEDs. An example of this is the simple four-stage level detector shown in Figure 7. The full-scale threshold (all LEDs on) is given by $V_{IN} = (R1 + R2)/R1$ volts. The other thresholds are at 3/4 full scale, 1/2 full scale, and 1/4 full scale. The output resistors limit the current into the LEDs.

Level Shifter

Figure 8 shows a circuit to shift from bipolar ±5V inputs to TTL signals. The 10kΩ resistors protect the comparator inputs, and do not materially affect the operation of the circuit.

Two-Stage Low-Voltage Detector

Figure 9 shows the MAX932 monitoring an input voltage in two steps. When V_{IN} is higher than the LOW and FAIL thresholds, outputs are high. Threshold calculations are similar to those for the window-detector application.

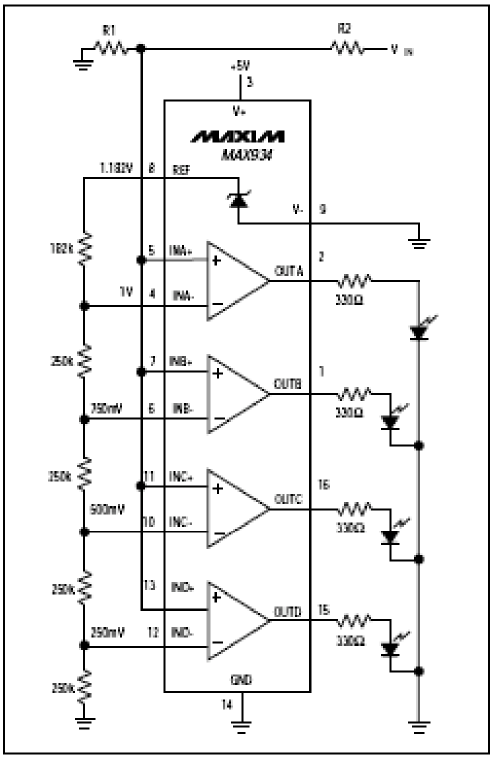


Figure 7. Bar-Graph Level Gauge

Comparatori Low Power

MAXIM

MAX...

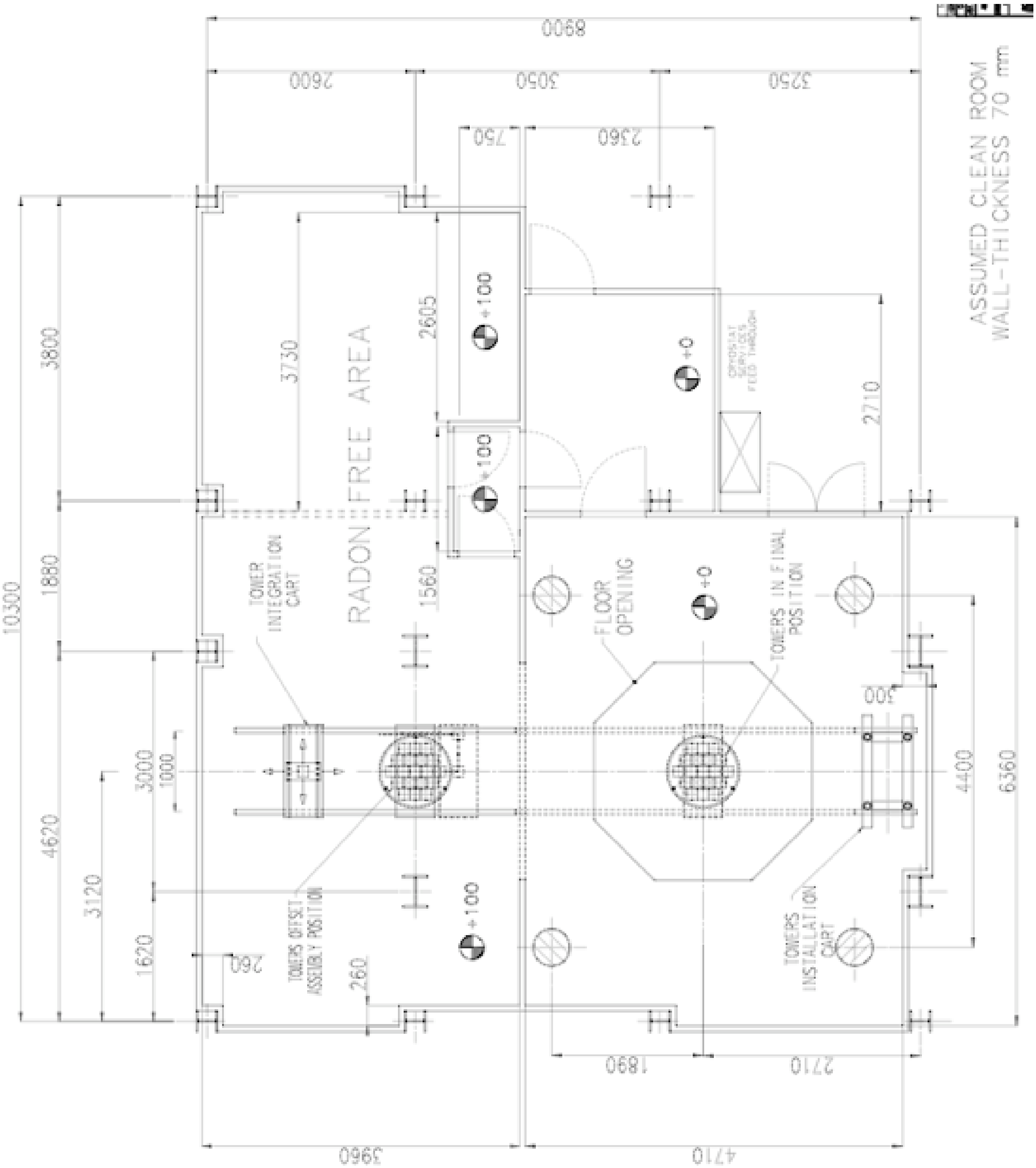
- Corrente di riposo soltanto 4 µA
- Riferimento Bandgap incorporato (1,182 V ±2%) e isteresi regolabile
- MAX 933 = MAX 932, tuttavia con entrata invertente al comparatore B

Tensione di alimentazione V_{CC} +2,5...11 V/±1,25...±5 V
Tempo di ritardamento t_{pd} 12.000 hs
Uscita continua di corrente 50 mA

Art.No	Tipo	Esecuzione	Descrizione	Contenitore	RoHS		Prezzo per 1 in EUR 1+	10+	50+	Magazzino	Quantità		
640304	MAX 921 CPA	Singolo	Ultra Low Power	DIL-8			4.80	4.35	4.00		1		
640305	MAX 921 ESA	Singolo	Ultra Low Power	SO-8			5.50	5.05	4.60		1		
642757	MAX 931 CPA	Singolo	Low Power	DIL-8			2.15	2.05	1.91		1		
642758	MAX 931 CSA	Singolo	Low Power	SO-8			2.97	2.82	2.64		1		
642759	MAX 932 CPA	Duplice	Low Power	DIL-8			4.17	3.97	3.70		1		
642760	MAX 932 CSA	Duplice	Low Power	SO-8			3.90	3.55	3.25		1		
642761	MAX 933 CPA	Duplice	Low Power	DIL-8			3.99	3.80	3.54		1		
643057	MAX 933 CSA	Duplice	Low Power	SO-8			3.80	3.55	3.33		1		

= conf. RoHS = non conf. RoHS = franco magazzino = verrà ordinato =aggiungere al carrello = ins. in elenco Prezzo in EUR, IVA esclusa

12.9. CUORE *Clean Room*



12.10. *Guide FESTO per garage*

Assi con trasmissione a vite DGE

Caratteristiche

Sistemi di posizionamento elettrici
Assi elettromeccanici

2.1

Come si presenta

- Guida precisa e robusta
- Elevata flessibilità grazie a molteplici soluzioni di fissaggio e di installazione
- Ampie possibilità di adattamento su attuatori
- Vasta gamma di accessori di montaggio per combinazioni multiassiali
- Gruppi motore-unità di controllo ottimizzati per l'applicazione

Esecuzione base DGE-SP

- Corse da 100 ... 2000 mm
- senza guida
- Ridotti parametri di carico

Con guida a ricircolo di sfere DGE-SP-KF-GK/-GV

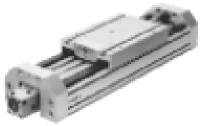
- Corse da 100 ... 2000 mm
- Slitta standard o slitta prolungata
- Parametri da medi ad elevati

Con esecuzione protetta DGE-SP-KF-GA

- Corse da 140 ... 1500 mm
- Guida e slitta sono protetti mediante copertura da particelle provenienti dall'alto e dal lato

Con guida per carichi pesanti DGE-SP-HD

- Corse da 100 ... 1500 mm
- Elevata precisione di guida
- Struttura robusta
- Parametri di carico elevati

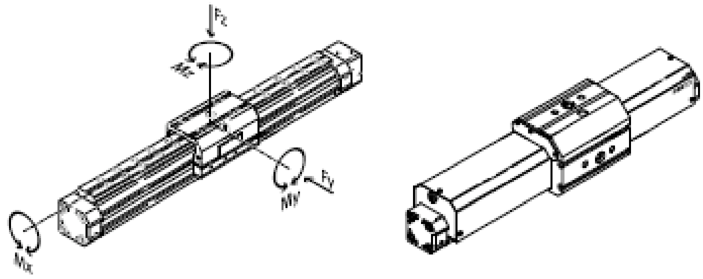


Assi con trasmissione a vite DGE-SP-KF, con guida a ricircolo di sfere

Foglio dati

Parametri di carico per l'asse con slitta standard GK o con esecuzione protetta GA

Le forze e i momenti indicati sono riferiti al centro della guida.
In condizioni di esercizio dinamico non devono essere superati i valori indicati. Per questo occorre prestare particolare attenzione alla fase di decelerazione.

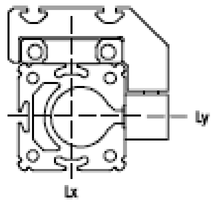


Se l'attuatore è soggetto contemporaneamente a più forze e momenti, oltre ad osservare i parametri di carico indicati si devono soddisfare le seguenti equazioni:

$$\frac{Fy}{Fy_{max.}} + \frac{Fz}{Fz_{max.}} + \frac{Mx}{Mx_{max.}} + \frac{My}{My_{max.}} + \frac{Mz}{Mz_{max.}} \leq 1$$

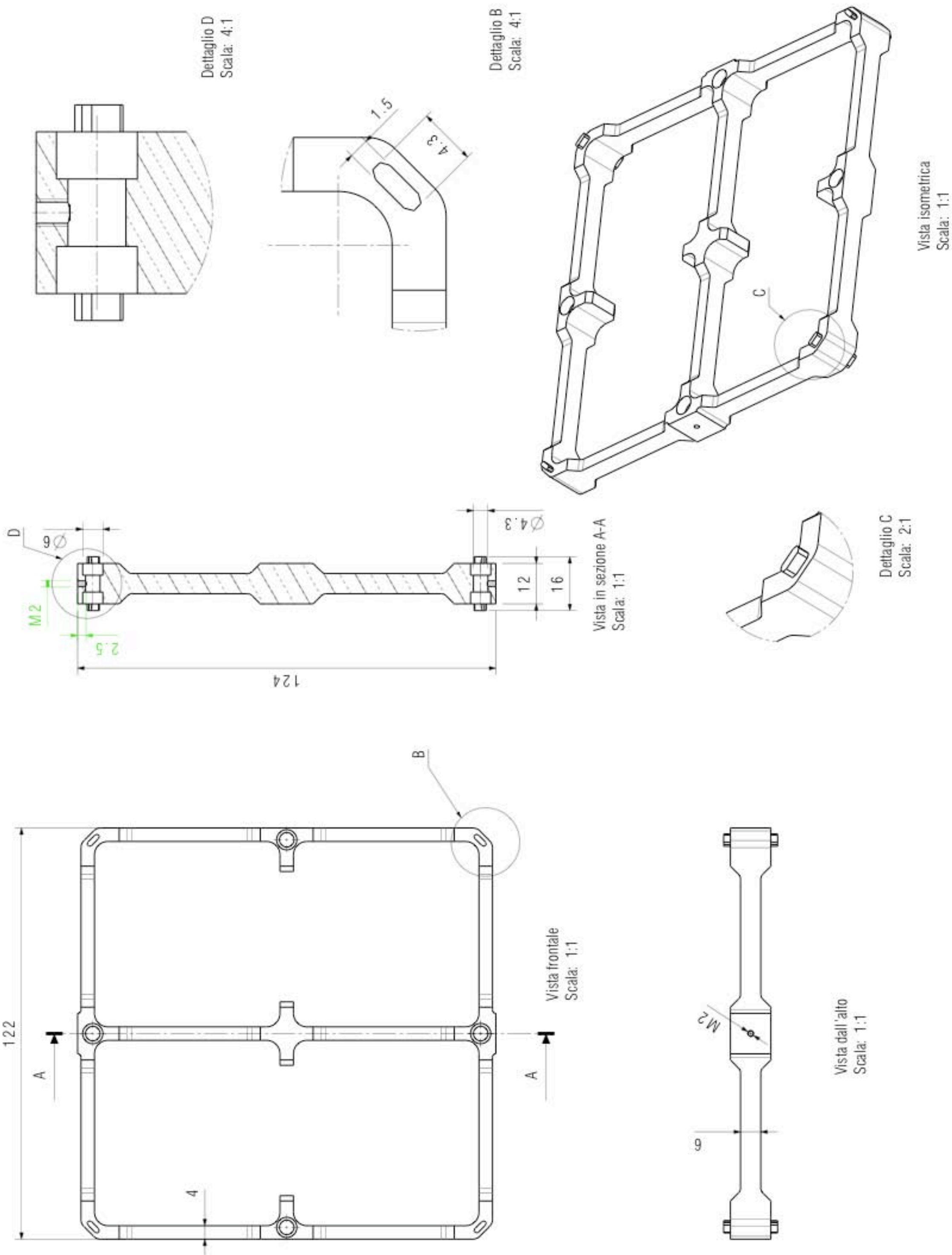
Forze e momenti ammissibili GK/-GA					
Dimensioni		18	25	40	63
$Fy_{max.}$	[N]	930	3080	7300	14050
$Fz_{max.}$	[N]	930	3080	7300	14050
$Mx_{max.}$	[Nm]	7	45	170	580
$My_{max.}$	[Nm]	23	85	330	910
$Mz_{max.}$	[Nm]	23	85	330	910

Momento di superficie di secondo grado

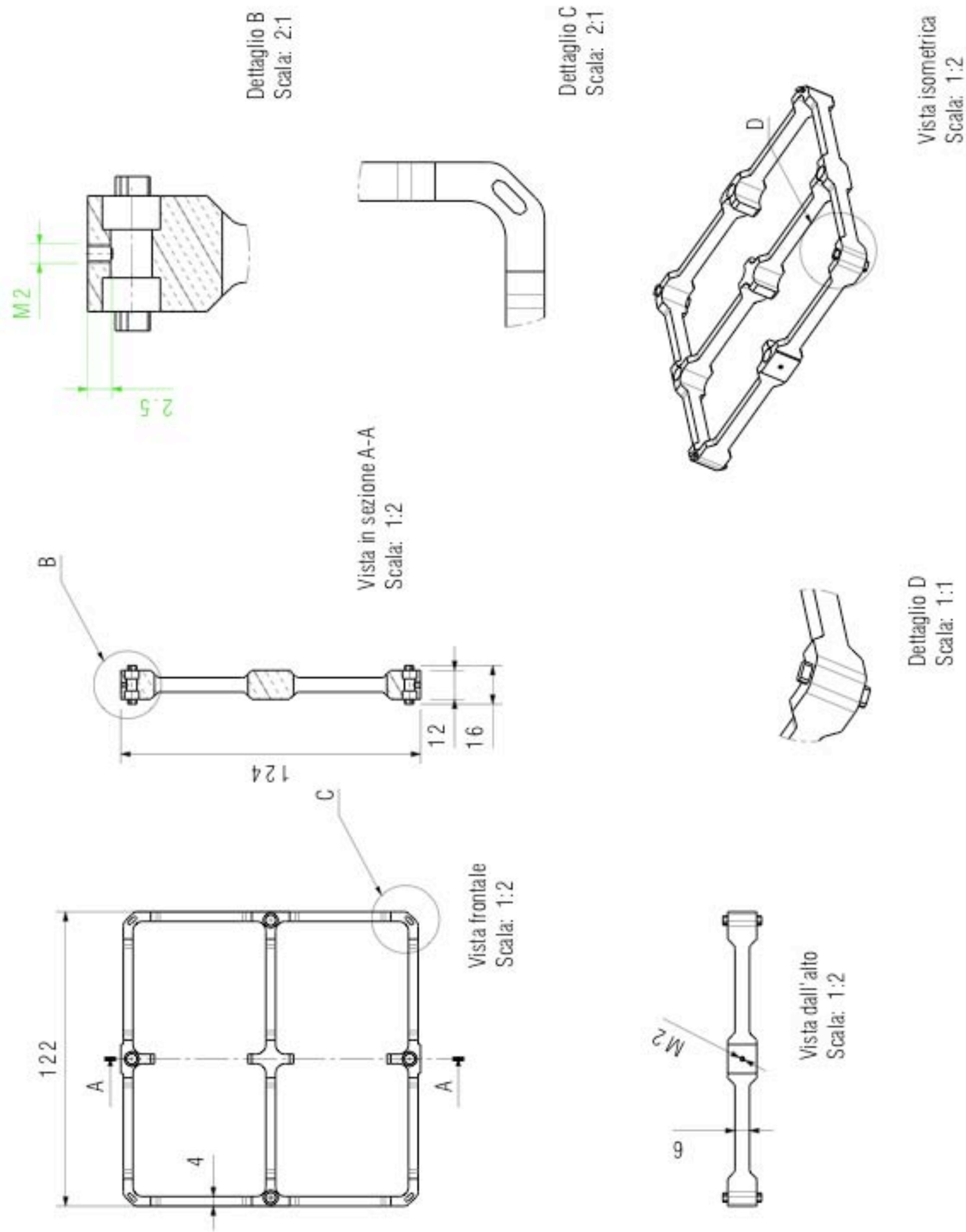


Dimensioni		18	25	40	63
Lx	[mm⁴]	$172,3x10^3$	$551x10^3$	$1908x10^3$	$13677x10^3$
Ly	[mm⁴]	$73,7x10^3$	$250x10^3$	$875x10^3$	$6987x10^3$

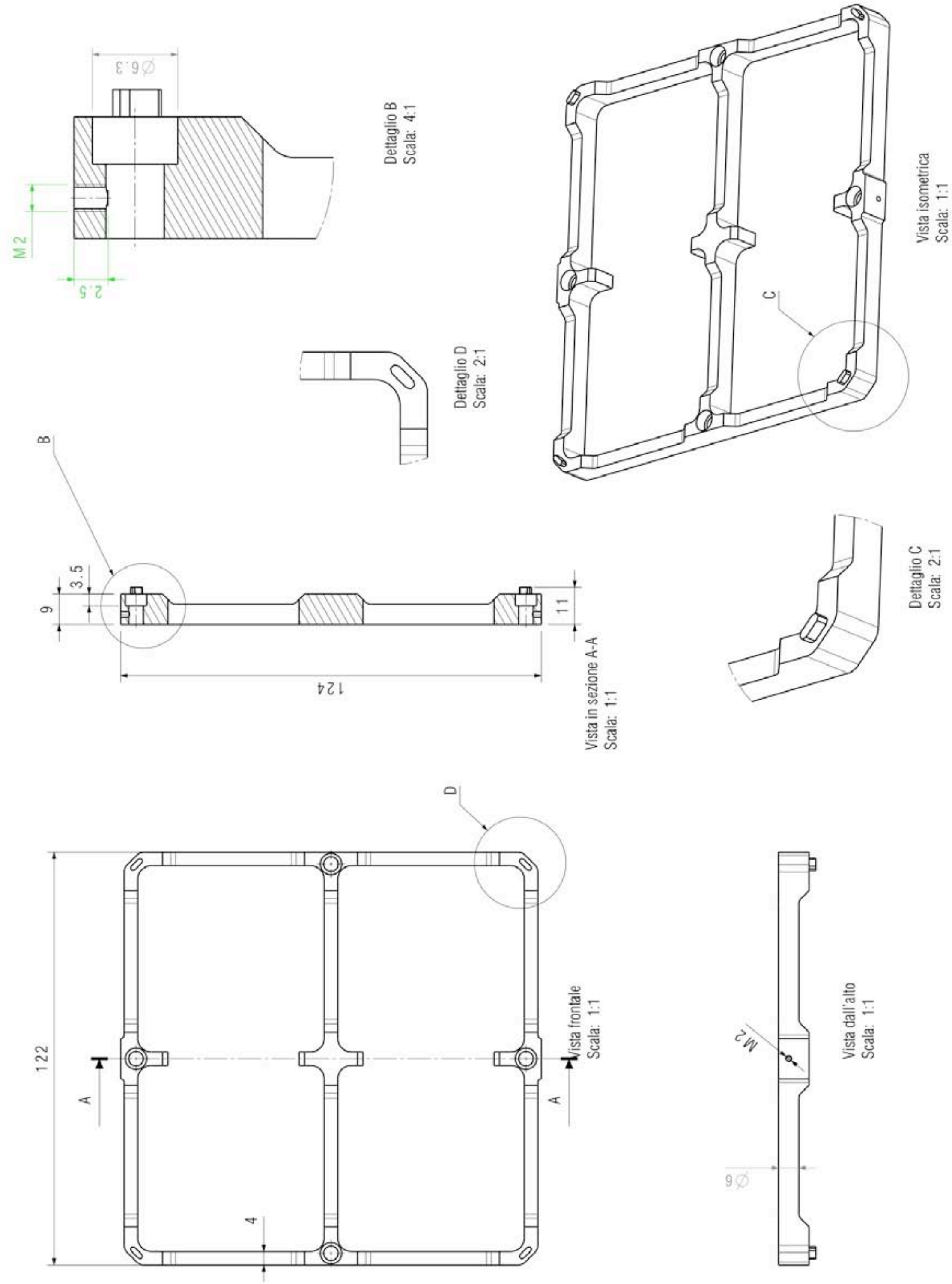
12.11. *Frame A*


Dettaglio D
Scala: 4:1
Dettaglio B
Scala: 4:1
1.5
4.3
Vista isometrica
Scala: 1:1
C
D
Ø6
Ø4.3
M2
2.5
12
16
124
Vista in sezione A-A
Scala: 1:1
Dettaglio C
Scala: 2:1
B
122
A
A
4
Vista frontale
Scala: 1:1
M2
9
Vista dall'alto
Scala: 1:1

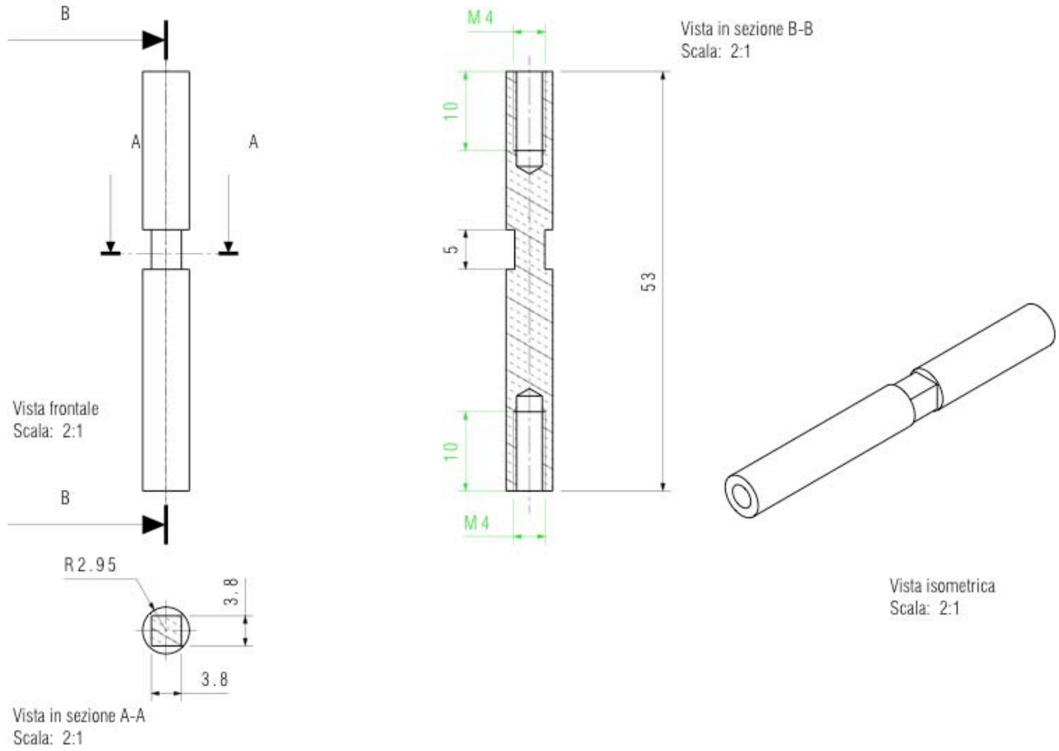
12.12. *Frame B*

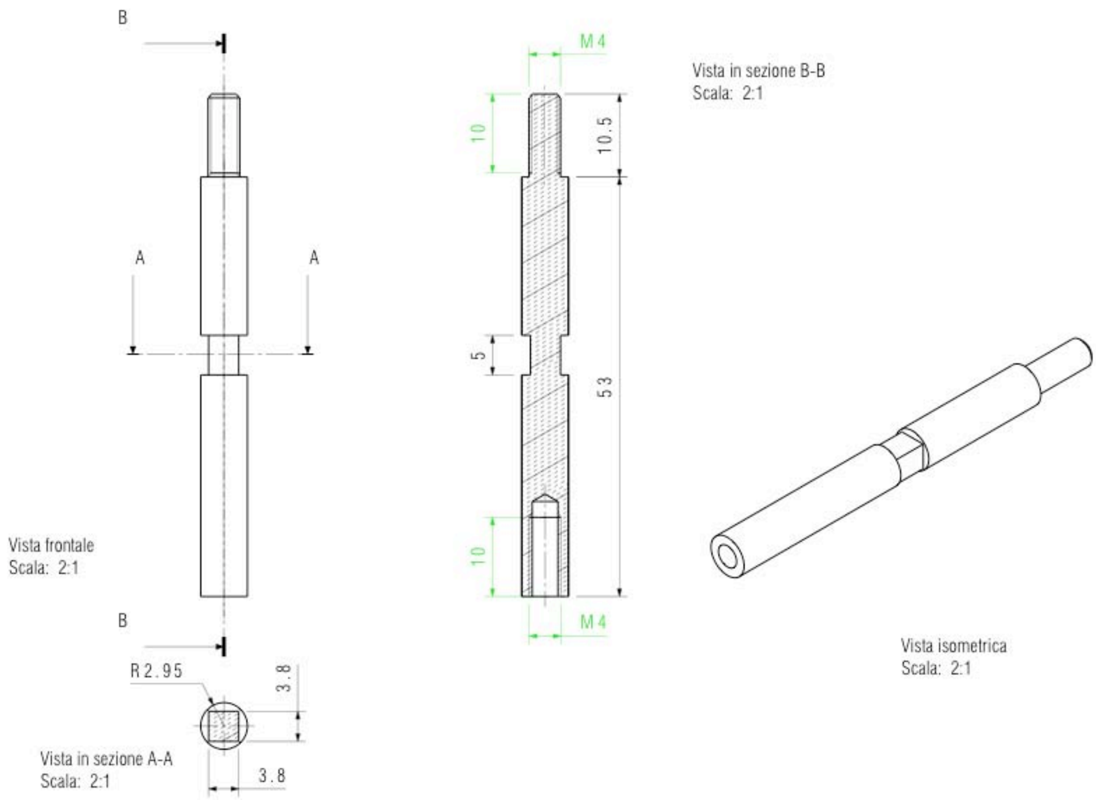

Dettaglio B
Scala: 2:1
M2
2.5
Dettaglio C
Scala: 2:1
Vista isometrica
Scala: 1:2
D
B
Vista in sezione A-A
Scala: 1:2
12
16
124
C
Dettaglio D
Scala: 1:1
122
A
A
4
Vista frontale
Scala: 1:2
M2
6
Vista dall'alto
Scala: 1:2

12.13. *Frame Top*



12.14. *Pillars*





12.15. CableRail